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THE ROMANCE OF MODERN PHOTOGRAPHY

THE ROMANCE OF MODERN PHOTOGRAPHY

ITS DISCOVERY & ITS ACHIEVEMENTS

BY

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"THE ROMANCE OF MODERN ELECTRICITY," "ELECTRICITY OF TO-DAY"
&C., &C.

WITH SIXTY-THREE ILLUSTRATIONS

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PREFACE

IT is not the author's purpose in the present volume to give any instruction in the practice of photography. There are many useful works dealing with the practical side of the subject. His object is to tell the romantic story of the discovery of this wonderful art, and the steps by which its range has been extended until it can achieve results which only a few years ago would have been thought impossible. A glance at the list of chapters will show what a wide field photography now covers, and what service it renders to man, both in his everyday life and in his most subtle scientific researches.

The story has been told in the most readable form that the author could give it; but in an Appendix will be found a record of the successive incidents in the history of the invention, with the dates, and the names of the inventors, in a shape convenient for reference.

The author is indebted to many friends for interesting information and references. Among these are Professor Korn, of Munich University; Professor Reiss, of Lausanne University; Professor Muir, of the West of Scotland Technical College; J. Craig Annan, William Lang, Patrick Falconer, and John Trotter, of Glasgow.

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CHAPTER I

HOW PHOTOGRAPHY CAME TO BE INVENTED

An amusing incident—Early invention of the camera obscura—Photography foreshadowed in early fiction—An interesting legend about one of the alchemists—Some early experiments in London.

THERE are few readers who require to have the general principles of photography explained to them. Almost every one is quite familiar with the dark camera, the exposure of the sensitised plate, the later developing and fixing of the image by chemical processes thereby producing a negative, and finally the paper picture obtained by contact printing by daylight. The general public were not always so well versed in photographic methods. I can well remember, some twenty years ago, when, in country districts, one found people surprised that the photographic artist "could draw that quickly"; the idea being that he drew the pictures by hand the while he disappeared beneath his focussing cloth.

One sometimes found well-educated townspeople failing to grasp the first principles of photography. I remember one incident when an early enthusiast was staying in the country. He wrote asking a friend, who was about to pay him a visit, to bring with him some photographic plates. The friend when he arrived explained that these photographic plates had given him a fright. He had let them fall by accident, and, fearing they might be broken, he had opened the box on the journey, and was quite relieved to find that there was not even a crack on any of the plates. We can imagine his feelings when he was informed that the plates having been once exposed to light were absolutely useless.

We have become so accustomed to photography that it will be of interest to see how man discovered this art. We hardly expect to find that photography was invented by a certain man on a certain date, and yet there must have been a first photograph. Our difficulty is to know which of the early attempts we can really call a photograph. There are, however, a few names which stand out very prominently in connection with the invention of photography. All invention is more or less an evolution; a simple association of ideas. The ideas and discoveries of one generation lead on to the further discoveries of the succeeding generation. In some cases progress is very slow, while in others vast strides are rapidly made. Previous to the dawn of the nineteenth century all scientific progress was necessarily slow, for information travelled very slowly. Man had to carry intelligence from one place to another. News could not then be flashed to the ends of the earth with lightning speed, nor did there exist any steamers to race across the oceans. Just as in the case of electricity we find an important discovery lying dormant for many centuries, so we find the basis of photography discovered hundreds of years before there was any practical application. To those who have not already considered the matter it may at first seem somewhat strange that the camera should have existed for nearly three hundred years before photography was invented.

In the middle of the sixteenth century there lived an Italian philosopher, Battista Porta, who exhibited what we know as a *camera obscura.* All he did was to put a tightly fitting shutter on his window, so that no light could enter, except by a small hole which he had cut in the centre of the shutter. This hole was in size rather less than would permit the little finger to pass through. When this was done there appeared upon the opposite wall of the room an inverted image of the outdoor scene immediately in front of his window. Indeed, there was a facsimile of the view he had from his window, except that everything was standing on its head. The philosopher went into raptures, crowds flocked to his house in Naples to see these "pictures painted by light, glowing with colour and marvellously accurate." It has been stated by many that Battista Porta invented the *camera obscura*, but there are records of such cameras prior to Porta's time. Many of us have probably seen the same phenomenon accidentally produced at one time or another. I can well remember, as clearly as though it were but yesterday, when, at the age of ten, I came downstairs early one bright summer morning before the outer front door had been opened, I was very much surprised to see on the ground glass of the inner door an inverted image of the fields and trees in front of the house, every detail being most faithfully reproduced. I can remember that I was not satisfied till I learned the cause of the picture being upside down. No doubt the reason for this is patent to most readers, but if not the matter will be made clear when we come to consider "Nature's Camera."

Battista Porta caused the image to fall upon a white surface so that the details might be more clearly seen; an experiment which may be very easily repeated by any one. About this time it was also found that the image could be improved by placing a glass lens at the hole in the dark shutter. This gave a much brighter and what photographers call a sharper picture. The lens was not a new invention. People were well acquainted with glass lenses; they were in common use long before this time, having been worn in spectacles for some two hundred and fifty years before this. The idea of glass lenses, wherewith to focus light, must have been of very early origin, for there may be seen in the Assyrian department of the British Museum a glass lens which was found in the ruins of Nineveh (1000 B.C.), that great city on the top of whose high walls three chariots could drive abreast around its sixty-mile circumference. There is, of course, the possibility that this ancient lens was merely used as an ornament.

The introduction of the lens into the *camera obscura* still left the image upside down. A mirror placed close to the lens caused the light to be thrown down through the lens on to a horizontal table instead of its falling

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Exasperation and Retaliation

These photographs make a story without words. These were taken by Miss Agnes Tomlinson in one twenty-fifth part of a second by means of a Thornton-Pickard Imperial Camera and studio shutter.

upon the upright wall. The observer could then view the picture in its natural position by merely taking his stand at the base of it without the necessity of standing on his head.

When it became known that the necessary apparatus was so very simple, these dark chambers or *camera obscuras* became a source of amusement in the country houses of the wealthy. We still find a few such instruments exhibited in large cities by way of entertainment. I remember how, many years ago, one of my mother's maids returned from a visit to the Scottish capital, filled with delight and wonderment at what she had seen at the "dispensary." It seemed strange that the girl should have included a dispensary in her sight-seeing, but on cross-examination it was found to be a *camera obscura.* Possibly her idea was that the light dispensed the picture upon the table.

The idea of trying to catch and fix these pictures of Nature may have occurred to many, but to the majority of people it would seem an absolute impossibility. Some early writers of fiction described Nature herself producing pictures; very possibly the idea was suggested by these sixteenth-century *camera obscuras.* Late in the seventeenth century one writer imagines himself transported to a far country where pictures were produced in the following manner. Great vessels made of gold and silver were filled with water. The surface of the water reflected the surrounding scene, but, strange to say, the water then froze and retained the picture permanently. About the middle of the eighteenth century another writer of fiction dreams he is in the very heart of Africa, where he is conducted by his guide into a darkened chamber. He saw out of a window a great sea which seemed to be a quarter of a mile distant. We can imagine his surprise upon seeing the ocean in the centre of Africa. It seemed to him a miracle, as his own words will show. "I hastily ran to convince my eyes of so improbable a thing. But in trying to put my head out of the window I knocked it against something that felt like a wall. Stunned with the blow, and still more with so many mysteries, I drew back a few paces.

"'Thy hurry,' said the guide, 'occasions thy mistake. That window, that vast horizon, those black clouds, that raging sea, are all but a picture. The elementary spirits have composed a most subtle matter, by the help of which a picture is made in the twinkle of an eye. They do over with this matter a piece of canvas, and hold it before the objects they have a mind to paint. The first effect of the canvas is that of a mirror. But what the glass cannot do, the canvas, by means of the viscous matter, retains the image. The impression of the images is made the first instant they are received on the canvas, which is immediately carried away into some dark place. An hour after, the subtle matter dries, and you have a picture so much the more valuable as it cannot be imitated by art or destroyed by time.'" So runs the tale, which was written by Tiphaigne de la Roche, in 1760, under the title of *Giphantie*. This was assuredly a fanciful dream, and yet it is a fair description or prediction of what we have now accomplished.

How many people may have made serious attempts to fix the image of the *camera obscura* is not known. At least three experimenters were successful, and of these two were natives of France, while the third was the grandson of an English earl.

What is the earliest date at which photography became possible? One might say that it would have been quite possible for Battista Porta to have in some measure fixed his Nature's drawings, as the necessary chemicals were known then to the alchemists. There is a legend that, just about the same time that this famous Italian philosopher was exhibiting his *camera obscura*, one of these alchemists, who was seeking in vain for the *philosopher's stone* or the *elixir vitæ*, chanced to drop some ordinary sea-salt into a solution of silver nitrate, whereupon the liquid became white like milk. This phenomenon by itself would not astonish the alchemist, but he observed that when sunlight fell upon this white liquid it very quickly turned black. However, as this new phenomenon did not seem to lead towards either of the goals for which the alchemist was striving, he did not reckon it of much importance. These old-time alchemists were by no means all rogues or charlatans; many of them earnestly sought after the *philosopher's stone* and the *elixir vitæ*. They really believed that they might succeed in transmuting the baser metals into precious gold and silver, and that they might also discover some panacea which would prolong life indefinitely. With the recent discoveries of radium and radio-activity, who can say that man may not some day see such transmutations of metals? We now see the immutable atom of a few years ago breaking up into other forms of matter; it is true this newly discovered action of Nature is only a transmutation on a very small scale, but scientists are not going to be dogmatic and say that it will for ever be impossible to hasten this process. Many scientists of a century ago even believed photography to be for ever an impossible thing.

I imagine that as regards the second goal of the alchemist—the indefinite prolongation of life—the most of us are ready to be dogmatic, despite the ingenious suggestions of Professor Metchnikoff, of the Pasteur Institute. This learned gentleman believes that were it permissible to prepare certain serums and inject them into the human body old age would be defied. However, to return to the alchemists, we find that they treated the study of chemical phenomena in very much the same spirit as the astrologers looked upon a knowledge of the stars. To the astrologer the only useful purpose in a study of the heavenly bodies was to enable him to foretell future events and perchance in some mysterious way to influence them. So it was with the alchemist; he treated his discoveries lightly if they did not seem to take him nearer his twofold goal. Nevertheless these men made many discoveries which are of much importance to us to-day.

Despite the existence of the legend to which I have referred, it seems doubtful whether or not the alchemists were really aware of the action of light upon silver salts, although it is certain that these men made silver nitrate. In any case, it was well known in the sixteenth century that silver ore sometimes changed colour when brought up from the mines. If the alchemists did know of this property of silver salts, it is clear that they did not consider the phenomenon of much importance; it is certain that the subject did not attract any attention. It is interesting to note that a German physician, some two centuries later, amused his friends by making up a mixture of chalk and silver nitrate in a bottle, and then exposing the bottle to sunlight. He cut out designs and words in cardboard, after the manner of stencils, and when he allowed sunlight to shine through these upon the contents of his bottle, there appeared the same design or word in black upon the chemical mixture. Shaking the bottle well caused the image to disappear, whereupon the bottle was ready for another performance. It has been suggested that this man should be called the inventor of photography—but he really only invented a conjuring trick. Leaving the alchemists out of account, this man may have been the first to note the darkening effect of light.

Early in the nineteenth century Wedgwood, a son of the famous English potter, made some interesting experiments with silver salts. Wedgwood was assisted in some of these experiments by the great Sir Humphry Davy, who did so much pioneer work for chemistry and electricity. These two experimenters coated paper, and also white leather, with a weak solution of silver salts. They then laid opaque objects upon the prepared surface, and thus caused the shadows of the objects to imprint themselves. In other words, the paper turned black on exposure to light, except at those places where the paper was protected from the light by the intervening objects. The result was a white print upon a black ground.

These experimenters tried some of their prepared paper in a *camera obscura*, but without any result. Their failure was no doubt due to the want of intensity in the light which passed into the *camera obscura*, for Davy afterwards succeeded in producing images of objects placed in a *solar microscope*[1] which had a more concentrated light. With a modern camera and ordinary photographic paper it is quite easy to take a photograph directly on to the paper in the camera, provided a sufficiently long exposure is given.

Wedgwood and Davy succeeded in copying paintings on glass by placing them in contact with a sensitised paper, but they do not seem to have considered the subject to be of much practical importance. They were not able to fix the image permanently; the light soon blackened the whole paper and therefore destroyed the picture. One may be a little surprised that our illustrious chemist, Humphry Davy, did not devise some means of fixing the paper print, and the surprise is increased when one learns that all that was really necessary was to dip the print in salt water. Wedgwood and Davy did make some attempts to fix the picture by washing the prints thoroughly and by coating the surface with varnish, but these methods failed to prevent the further action of light. Referring to the possibility of fixing such prints, Davy wrote: "Only this is wanting to render the process as useful as it is elegant." I have said that one may be surprised to learn that Davy failed in overcoming so simple an obstruction, but I cannot think that he really gave the matter any very earnest attention, for he was at this time deep in chemical and electro-chemical research work, which, no doubt, appealed to him as being of far greater importance. It may be remarked in passing that these experiments made by Wedgwood and Davy had also been

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[1] The solar microscope was practically a sunlight magic lantern.

made abroad more than half a century previously, but these two English experimenters do not appear to have been aware of this fact.[1]

This is how matters stood at the beginning of the nineteenth century, and indeed at the time when our late Queen Victoria was a girl. Then followed three separate romances, the discoveries of Niépce, Daguerre, and Talbot, the three pioneers already referred to, the first two being French and the third an Englishman.

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[1] Names and dates not detailed in this chapter will be found in the Appendix at page 337.

CHAPTER II

EARLY PHOTOGRAPHS ON SILVERED PLATES

Large prices paid for early photographs—The reason why—A famous scene painter—"Is Daguerre mad?"—Daguerre finds he has a rival in Niépce—Strange story of another unknown rival—How Niépce made his pictures—Daguerre and Niépce enter into partnership—An accidental discovery makes photography a practical success—How daguerreotypes were made—Daguerre fails to float a company—A great speech in the French Chamber of Deputies—Government pensions for the inventors—Have the historians misrepresented Daguerre's character?

MANY of us have in our possession small leather cases or frames containing pictures of our grandparents. These pictures are on metal and are usually protected by a glass cover. These are the earliest productions of photography, and are known as daguerreotypes, having been so called after the inventor of the process. There are doubtless some elderly people now living who can remember the opening of the first studios for the production of these pictures in 1840.

Our grandfathers did not have their photographs taken so often as we do; it was in their time a very expensive luxury. Our own calls upon the photographer would be less frequent if we had to pay from two and a half to four guineas for one single copy, and yet these were the actual prices paid during the first fourteen years. Why such exorbitant prices? In the first place the photographer could not accept an order for a dozen copies; he could only give the one copy which he took in the camera. Then again the picture was produced on a polished silver surface and considerable skill was required, especially in the preparation of the plate, so that the prices were really not so exorbitant. The case was very different from that of the photographer of the present day, who may receive orders for several dozen photographs all produced at small expense from one single negative.

Those who possess daguerreotypes should preserve them, as they are becoming rare. In the accompanying illustrations (facing p. 30), we have photographs of two of these early daguerreotypes, taken nearly sixty years ago. The daguerreotype in the left-hand illustration is in the possession of the West of Scotland Photographic Society, who kindly gave me permission to copy it. The right-hand illustration is from a photograph of a daguerreotype, the original of which cannot be found by a friend who has very kindly been searching for it. This daguerreotype is of historic interest, as it not only shows the late Queen Victoria and the Prince Consort, but also Napoleon III and his wife. It was taken in 1854, when the 1851 Exhibition buildings were reopened as the Crystal Palace.

It will be of interest to follow Daguerre's career so far as that relates to the invention of this process of photography which bears his name. Early in the nineteenth century Daguerre distinguished himself as a scene painter for the theatres in Paris. He had been somewhat neglected by his parents and allowed to drift into any occupation that attracted him. Daguerre was an enthusiast, and in addition to exhibiting originality as an artist, he introduced many ingenious stage effects. Along with another artist he painted a diorama, which was a kind of panorama with what we should now call "dissolving views" in connection with magic lanterns. This was shown in Paris in 1822 and brought Daguerre much fame. He, and many other artists, made use of the *camera obscura* when making sketches from Nature. Our old friend Battista Porta made this suggestion at the very outset. Sometimes the artist would carry a small dark tent with him, wherein he would sit and make sketches from the picture "drawn by Nature" upon the white screen before him. Daguerre became possessed of a great desire to fix those pictures without requiring to copy them. He became so enthusiastic about this that he is said to have spent nine-tenths of his whole time in his laboratory. As time went on, his wife became alarmed. Was her husband going mad? Was he striving after something which was perfectly ridiculous? She consulted one of the well-known men of science, but the most comforting assurance she could get was to this effect: "In our present state of knowledge it is impossible, but it may not always remain an absolute impossibility."

Daguerre's first attempts were with paper soaked in silver salts; just such experiments as had been tried by Wedgwood and Davy, as related in the preceding chapter. Despite all his patient toiling, Daguerre seems to have met with little success in this direction, although we have already seen that the thing is possible, provided sufficient light enters the camera.

It so happened that the optician in Paris from whom

Daguerre bought his apparatus, and who was aware of Daguerre's experiments, chanced to have, as a customer, another scientific enthusiast, who was earnestly seeking after the same goal. This other would-be inventor was Joseph Nicéphore Niépce, who lived far away from Paris, at Chalons-sur-Saône. Niépce[1] was of a much more reticent nature than Daguerre, and, living at a distance, his calls at the optician's shop were much less frequent than those of Daguerre, who called regularly once a week. The Paris optician, Charles Chevalier, informed Daguerre that another gentleman was also making experiments, with the hope of fixing the image of the *camera obscura*. Daguerre thereupon wrote to Niépce informing him that he too was busily engaged upon this subject, but Daguerre received no reply to his letter. Niépce put the letter in the fire, believing it was merely a ruse on the part of some one anxious to obtain his secret. In about twelve months Daguerre tried again to get in touch with Niépce, stating that he had arrived at important though imperfect results. Daguerre suggested that it might be advantageous to both if they were to make a mutual exchange of their secrets. Niépce made inquiries regarding Daguerre, and evidently was satisfied that his claims were genuine, for a correspondence was begun between these two inventors, who, later on, exchanged samples of their work, and ultimately met, and signed a co-partnery agreement. Each partner agreed to make known to the other his present and future achievements.

In the preceding chapter I remarked that the idea of

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[1] There seems to be some question about the proper pronunciation of this word, but the best authorities pronounce it *Nee-eps*.

trying to fix the image of the *camera obscura* may have occurred to many people. There was at least one other man working at this problem in secret, and he evidently met with considerable success. His existence might never have been made known to us, but for a chance call which he made at Chevalier's shop. Chevalier tells us that one day a very shabbily dressed young man entered his shop and inquired the price of a certain camera. The man was pale and miserable-looking, and altogether very unlike the probable purchaser of a camera. When Chevalier told him the price the young man looked very disappointed, and stood dumb. The optician asked him if he might inquire to what purpose the young man proposed putting the camera. The youth hesitated a moment and then said that he had succeeded in fixing the image of the camera on paper, but that he had only a very rough piece of apparatus to work with. He declared, however, that he had already obtained such good pictures from his window that if he could only get a good camera his invention would be perfect. Chevalier thought to himself —another poor fool striving after the impossible. Possibly he gave outward signs of his disbelief, for the young man produced from an inside pocket a very tattered-looking pocket-book. We can imagine Chevalier's surprise when the young man laid upon the counter a view of Paris. Chevalier could not control his astonishment—it was quite clear that this picture was not the work of the hand of man; it could not be mistaken for a drawing, nor for a painting in black and white.

This struggling inventor seems to have been very frank about his methods, for he handed Chevalier a bottle of a blackish fluid, with which he said he had obtained the picture. The young man promised to return, but never appeared again, and we can only guess that his fate was a sad one. It is even possible that he may have died of want, or dragged out his remaining days in some obscure alms-house. One feels inclined to speculate as to what might have been, had Chevalier only thought of lending the poor fellow the necessary apparatus, and giving him some assistance until his invention was perfected. We might then have had this unknown man's name handed down as the inventor of photography, for this event occurred in 1825, at which date neither Niépce nor Daguerre had produced such pictures. However, it is very probable that Chevalier did not mean to lose sight of this remarkable youth. No doubt Chevalier was so much surprised at the whole meeting that it did not occur to him even to ask the stranger's name and address.

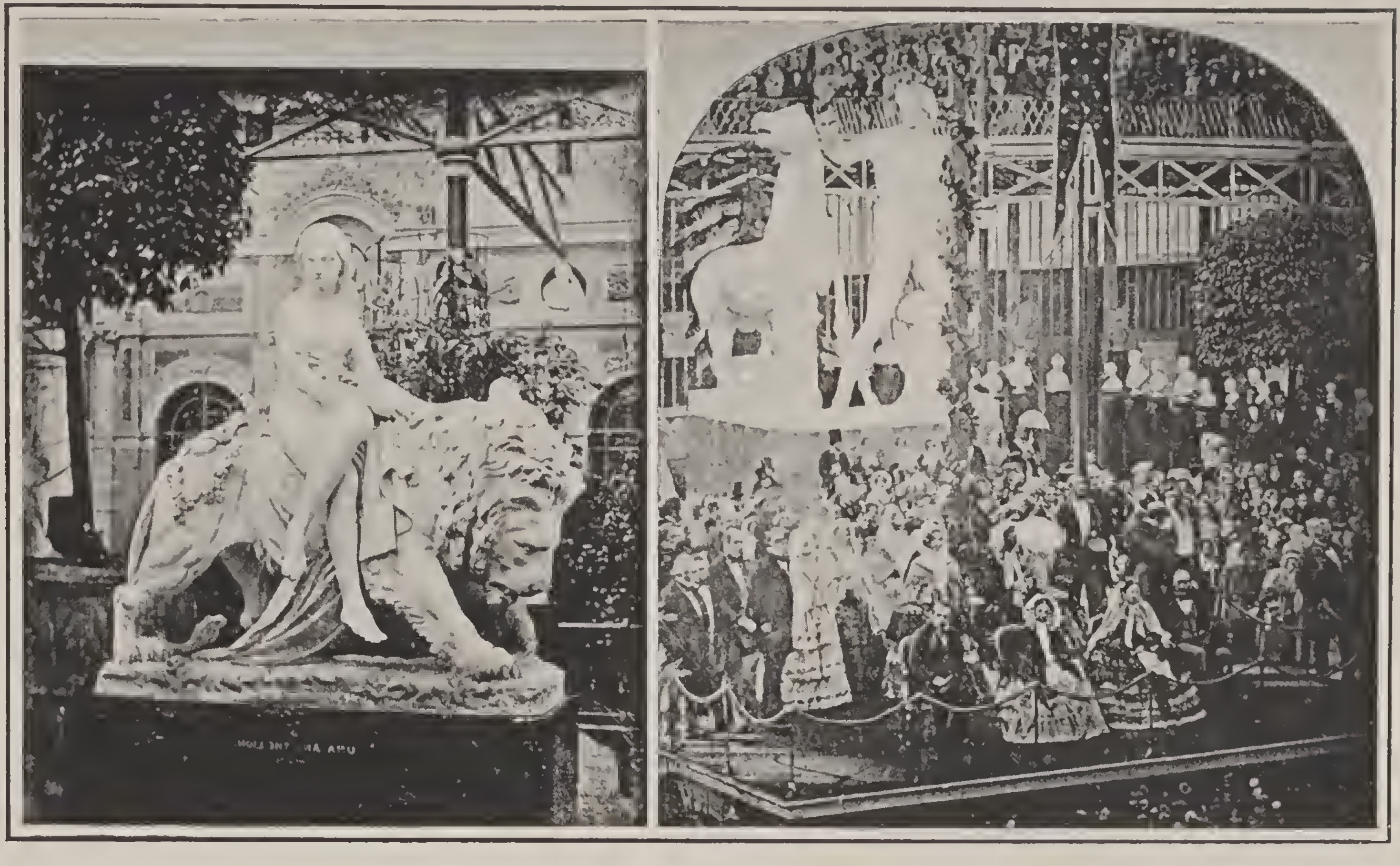
Chevalier tells us that he tried to fix the image of the camera by means of the solution which the stranger left with him, but without success. It is most likely he did not know how to handle the solution; indeed, it is possible that he may have exposed the liquid to light and thus rendered it useless before he ever tried to make use of it.

Chevalier informed Daguerre of this stranger's visit, and he gave the remainder of the solution to Daguerre, who also failed to get any result. The fact that Chevalier actually saw the "photograph" himself is, however, proof of the genuineness of the young man's claims.

To return to Niépce, who was more fortunate in possessing an ample supply of this world's goods; we find that Niépce had been at work upon this problem for ten years before he met Daguerre. It was generally known at this time, at least among chemists, that many substances were affected by light. The tanning which our faces get in summer at the seaside might suggest to the least observant that sunlight produced some chemical effect upon the skin, even were he ignorant of the cause of the negro's colour.

There was a mineral substance, doubtless of vegetable origin, which is known as bitumen of Judea; a sort of asphalt or pitch, and sometimes called "Jew's pitch." This material when dissolved with some oils was affected by exposure to light, but an exposure lasting many hours —and in sunshine—was necessary. It is not quite clear whether Niépce discovered this property of bitumen, or whether it had been previously observed. Niépce spread his preparation of bitumen upon a tablet of plated silver or well-cleaned glass. There were many careful operations required, and some knowledge of the great care which was necessary may be gleaned from one sentence in Niépce's description of his process. In explaining that the prepared plate must be protected from a damp atmosphere, he says: "In this part of the operation a light disc of metal, with a handle in the centre, should be held before the mouth, in order to condense the moisture of the breath."

At first Niépce contented himself with making contact prints on these prepared tablets, just as Wedgwood and Davy had done on paper soaked in silver salts. After meeting with success in reproducing engravings, etc., the paper being made translucent by oiling or waxing it, Niépce endeavoured to secure the image of the *camera*



Two Early Daguerreotypes

The photographs, from which the above have been reproduced, were taken on silvered-copper plates, at the opening of the Great Exhibition of 1851 (London). The right-hand photograph is of particular interest. The four figures in the front are Napoleon III., Queen Victoria, the Empress Eugenie, and the Prince Consort. (See chap. ii.)

obscura. The action of the light was such that those parts of the preparation exposed to it were so altered in chemical condition that they became insoluble in the oils by means of which the bitumen had been previously dissolved. This was very convenient; it allowed Niépce to dissolve away all the bitumen except those parts which had been affected by light. The result was that the remaining parts of the film produced only a silhouette, or black profile of the picture of the *camera obscura.* For his earliest experiments Niépce used a camera made out of a cigar box, with a lens taken from an old solar microscope belonging to his grandfather. One great cause of defect in those pictures must have been the very long exposure necessary. This extended sometimes to six or eight hours, and during that time the shadows on the scene being photographed would have moved practically right across the plate.

When the partnership was entered into between Niépce and Daguerre, the former seems to have been able to produce the best results. Daguerre soon made many improvements in Niépce's process, and he evidently abandoned his previous experiments with silver salts altogether. However, Daguerre soon became dissatisfied with the long exposure necessary, and he earnestly sought after some quicker process.

It may be remarked in passing that Niépce did not call his process photography but heliography, or sun drawing. Niépce died in 1833, before any commercial success had been attained, and the process which did meet with success was quite different from that at which Niépce had been working. It is said by many writers that Niépce's son who followed him in the partnership was quite willing that the successful process should be called "daguerreotype," thus taking no notice of the Niépce-Daguerre agreement. I think there must have been some error on the part of these historians, for there was a book published in Paris, in 1844, by Niépce's son, which seems to contradict this statement. Its title translated into English reads, "History of the discovery improperly called 'daguerreotype,' preceded by a notice of the real inventor, the late M. Joseph Nicéphore Niépce, by his son, Isidor Niépce." In the light of this publication the general statement that Niépce's son agreed to the title seems quite untenable.

Before his meeting with Daguerre, Niépce senior had visited his own brother in London. He had taken with him some of his pictures, presumably photographic copies of engravings. It was suggested that he should read a paper, relating to his heliography, before the Royal Society, but as he was not willing to divulge the particulars of his process the Society could not accept the paper. Niépce did not consider his process by any means perfect, and he was therefore unwilling to publish an account of it. Niépce only lived a few years after he entered into partnership with Daguerre, and it was not till about five years after the death of Niépce that Daguerre made the discovery which made photography practicable.

How then did this discovery come about? It happened in a most interesting manner. Our interest is always stirred by any discovery made by accident. It is certain that the first man who observed that silver salts were blackened by exposure to sunlight must have made the discovery by accident. He was not seeking to discover a substance which would be blackened by sunlight. The discovery of the principle of the camera obscura in the middle ages, no doubt, could be classed as accidental, but not so the experiments of Wedgwood and Davy, nor those of Niépce. These experiments therefore appear more commonplace. As children our interest was stirred by such stories as that of Archimedes, the ancient mathematician (287 B.C.). We could sympathise with him in his difficulty of how to find what quantity of alloy had been fraudulently mixed with the gold in the "pure gold" crown ordered by King Heiro. And when Archimedes visited the baths, still thinking of his problem, and observing that his body displaced a certain amount of water, which he reasoned must equal the weight of his body, we could enter into his excitement as he rushed home, undressed, shouting, "Eureka! Eureka!" ("I have found it! I have found it!"). Daguerre's excitement similarly knew no bounds when he first imperfectly fixed the image of the camera obscura. He exclaimed, "I have seized the light! I have arrested his flight! The sun himself in future shall draw my pictures!"

Daguerre had abandoned the bitumen process of his late partner Niépce, as also his own early experiments with silver salts, but he was evidently seeking once more to engage silver, in some form or another, in his service. It is said that Daguerre accidentally discovered that a plate treated with iodine was sensitive to light. We are told that on one occasion he noticed that a plate which had been treated with iodine retained the image of a silver spoon which had chanced to be laid down upon it. Although I can only find one historian who has preserved this tale for us, it seems a very probable one. Daguerre had already seen Niépce use iodine to blacken his bitumen pictures, so that iodine would be sure to be among Daguerre's stock of chemicals. It would be quite natural that he should try to improve his own pictures by exposing them to the vapour of iodine, just as Niépce had done, and no doubt it would be upon a plate which he had thus treated that he accidentally discovered the image of a spoon. This would suggest to him at once that iodine would make his silver plate sensitive to light.

This iodine, with which Daguerre was working, had not been long discovered. It is an elementary substance, and was obtained by some chemical manufacturers from seaweed. Daguerre took a brightly polished plate of silver and sought to make its surface sensitive to light by exposing it to the vapour of iodine. Alas, when Daguerre exposed his plate in the camera, he could only get a very faint sort of image of bright objects, and that after many hours of exposure. It seemed as though the hopes which he had built upon his silver plate, with its coating of iodide of silver, was going to share the same fate as his earlier experiments with paper soaked in silver salts ; indeed, matters looked even more hopeless. It so happened that one day he removed one of these silver plates from his camera, as the exposure—probably due to poor light—had been insufficient to produce any image. Had the spoilt plate been a glass one or a prepared paper it would doubtless have been immediately consigned to the rubbish heap, but being made of silver it was naturally laid aside in a cupboard to be repolished and again prepared for a fresh exposure. How many of us would have lost heart at this point and abandoned the whole affair as a practical impossibility! Not so with the indefatigable Daguerre. It was no light task to repolish the silver plate; it required great skill and care. I fancy that Daguerre must have come forward to open his cupboard next morning with a feeling of dogged perseverance; nothing for it but to "try, try, try again." Imagine his surprise, when he took the spoilt plate from the cupboard, to find an exquisite picture upon it. Doubtless he questioned whether he was waking or dreaming; it was too like a fairy tale. A perfect picture! Nothing approaching it had ever been seen by man before. Wherein could lie the magic power of his cupboard? Will another short exposure in the camera—another twenty-four hours of imprisonment in the cupboard—present him with another "perfect picture"? I very much doubt if Daguerre slept the following night. At any rate, there would be no chance of his sleeping on and failing to remove the second plate on the expiry of twenty-four hours. Another picture did appear, and equal in every way to the first, and so it only remained for Daguerre to discover wherein lay the magic of his cupboard. It was clear that the plate must have been affected by vapours from some of the chemicals in the cupboard, and so a little patience would be required to find out which particular dish of chemicals was the "good fairy." I think that the one which did prove itself to be the magical one was probably one of the last that Daguerre would have suggested. It was a simple dish of that bright semi-liquid metal known as mercury. In this way Daguerre discovered that if what he had previously considered to be a very much under-exposed plate was exposed to the vapour of mercury, the invisible image was gradually built up into a visible picture. What really happened was that the mercury vapour attached itself to the sensitive plate in exact proportion to the amount of light which had previously affected the plate while in the camera.[1]

Here we have the sensitive plate receiving a latent image, which only appears when chemically developed. To the photographer of to-day this has ceased to be a marvel, but to Daguerre and his compatriots it was indeed a true romance. The whole world was interested. It is difficult for us fully to realise their surprise. The wonderfully faithful picture produced by the new art was described by one French journal in this fashion: "In a view of Paris we can count the paving-stones, we see the dampness produced by rain; we can read the name on a shop." Indeed, the pictures were so good that many thought that all artists must pack up their paint-boxes and learn some other art. We are somewhat surprised to find the great historical painter, Paul Delaroche, sharing in this idea. When shown one of Daguerre's pictures he exclaimed, "Painting is dead from to-day." Little could

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[1] It has been questioned whether this effect could be produced by mercury at ordinary temperatures. One physicist assures me that mercury does give off a vapour at ordinary temperatures, and that he believes there would be sufficient to account for Daguerre's accidental experiment. We must remember that the plate was exposed for about twenty-four hours to the influence of the mercury. If any one doubts the possibility of mercury at ordinary temperatures being able to account for Daguerre's historical discovery, then we have only to imagine that the temperature of his cupboard was more than ordinary.

they then foresee that photography would prove a most useful handmaiden to the art of painting.

Despite all the good things that were said of the new art, the Parisians seem to have had no great hope of its commercial success, for when Daguerre tried to form a company to work his invention, he completely failed to float the shares. No doubt it seemed to be too good to be true. It may be that even those who knew something of former experiments could not believe that these "drawings by Nature" would be permanent, although Daguerre had succeeded in fixing the pictures by washing them in a solution of common salt. By this means the remaining iodide of silver which had been unaffected by the light was washed away, so that there could be no further chemical action. Sir John Herschel, the famous astronomer, suggested later that hyposulphite of soda was a better substance than common salt (chloride of soda) wherewith to fix the image. This "hypo" fixer has reigned supreme to this day.

It is a little difficult, at first, to see how the daguerreotype picture was produced. The foundation was a copper plate, with a brightly polished silver surface, and this was rendered sensitive to light by exposing it to the vapour of iodine, thus forming a film or coating of iodide of silver. If this prepared plate was exposed to the vapour of mercury there was no effect; but if any part of the plate was first exposed to light a chemical change took place in the iodide of silver, and the vapour of mercury would then adhere to those parts of the plate which had been acted upon by light.

Let us follow the taking of a portrait. The photographer first exposes his highly polished silvered plate to the vapour of iodine, and protecting this from the light, he places it in his camera. When he removes the cap of the camera lens, a good deal of light will be reflected into the camera from the sitter's face, and very little light from his black coat. The light from the face, falling upon the sensitive plate, effects a chemical change in the iodide of silver film at that place. There being practically no light reflected by the black coat, the film will remain unaffected where that part of the image falls, and so on with the other parts of the picture.

When the plate is removed from the camera, still shielding it from the light, it is exposed to the vapour of mercury. The mercury vapour attaches itself to those parts of the film which have been attacked by light, and thus the *high lights* or white parts of the picture are formed. The more the film has been affected by light the greater grabbing power it has for the mercury vapour. Those parts of the film which, like the image of the black coat, have not been affected by light will accept no mercury vapour. When the plate is then washed in a bath of common salt, or hyposulphite of soda, this unaffected iodide of silver is dissolved, leaving the foundation plate to show through at such places. It is this fact which makes it difficult to understand, at first, how the positive picture is obtained, for the black coat is really represented by a patch of brightly polished silver. This ought to look white, and not black. So it will, if a bright light is directly reflected by it, and if one holds a daguerreotype at a particular angle one does see the black coat to be white. The plate must be so placed that it reflects only dark objects, and then the picture is seen as a positive in place of a negative. A familiar illustration might be drawn from the art of bookbinding. We often see a device in gold on a bookbinding in which parts of the gold are frosted and parts polished. The polished parts look darker than the frosted in some lights, and brighter in others. We therefore picture the mercury as frosting the polished silver.

These early daguerreotypes were very delicate, the slightest touch of a finger being sufficient to spoil them. They were also very quickly tarnished by the atmosphere. These defects were in some measure overcome, at a later period, by a process of gilding the picture.

Having failed to float his company, Daguerre confided in M. Arago, one of the greatest scientists of his time. Daguerre showed his pictures to this great philosopher and astronomer, saying that henceforth Nature would depict her own likeness with a pencil of light. Arago was astonished at the beauty of the pictures and heartily endorsed the hopes of the inventor. Daguerre must have felt from that moment that his victory was won, for Arago was not only a learned professor, but also a leading politician, being at that time a member of the Chamber of Deputies. Arago soon gained for Daguerre the interest of other men of science. As it became clear that this new invention would prove of world-wide interest, these men brought forward a Bill in the Chamber of Deputies, recommending the House to grant annuities to Daguerre and the son of Niépce. The inventors could not have had a more able spokesman than Arago. A full House had assembled to learn more of this marvellous discovery, and that they were impressed with Arago's speech is evident, for the proposed pensions were unanimously agreed to—six thousand francs per annum for Daguerre and four thousand for Niépce junior. The reason for Daguerre's larger pension seems to have been that he agreed also to make public the methods by which he produced his wonderful diorama and stage effects.

The following sentences occur in M. Arago's address to the Chamber of Deputies: "The daguerreotype demands no knowledge of drawing, and does not depend on any manual dexterity. Any one may succeed with the same certainty as the author of the invention. The promptitude of the method is perhaps that which has most astonished the public."[1]

When the Bill came up before the Chamber of Peers, it was pointed out that if the invention were left the secret of an individual it would long remain stationary, but if presented to the world at large it would be "extended and improved by a general emulation." Therefore it was argued that the Government should grant the pensions and make the knowledge public property.

One condition made by the Government was that the inventors should make known all further improvements. Arago made the following reference to this in his address: "The importance of this latter engagement will certainly not appear doubtful to any person when we inform you that a very slight advance beyond his present progress will enable Mons. Daguerre to apply his processes to

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[1] Exposures had been reduced to about a quarter of an hour at this time, which seemed remarkably quick compared with the time required to paint or draw a picture.

executing portraits from life." We shall see from a later chapter that the necessary improvement was accomplished by an Englishman within one year from the date of Arago's speech.

All those who have written upon the history of photography agree in saying that it was a distinct condition with the French Government that the invention should be a present to the whole civilised world. Then each writer makes a remark to the effect that "notwithstandstanding, Daguerre took out a patent for his process in England." This has always seemed to me to cast a rather discreditable side-light upon the character of Daguerre. Anxious to find if there was not possibly some misunderstanding about this, I recently paid a visit to a Library of Patents. At first I could not find the patent referred to, as Daguerre's name does not appear in the index of patentees. I did not doubt that a patent had been taken out, and knowing approximately the date, I had no difficulty in finding it. It was taken out by one Miles Berry (a London patent agent) in his own name. He explains that the subject of the patent is "a communication from a foreigner residing abroad."

In another part of the text, which was evidently written some time after the patent was sealed, Miles Berry says: "I believe it to be the invention or discovery of Messrs. Louis Jacques Mandé Daguerre and Joseph Isidore Niépce, junior, both of the kingdom of France, from whom the French Government have purchased the invention *for the benefit of that country.*" The italics are mine, and are merely to emphasise these few words. It is clear, therefore, that "the foreigner residing abroad," presumably

Daguerre himself, did not read the agreement with the French Government in the same way as historians have done since then.

Miles Berry, who took out the patent, explains that he applied for it in the middle of July (1839), whereas the agreement with the French Government was not made till the following month. And further that the patent passed the Great Seal "on the second day of August, now last past, *which is some days prior to the date of the exposition of the said invention or discovery to the French Government at Paris by Messrs. Daguerre and Niépce.*" The italics are again mine, and in seeking to defend Daguerre I would bring forward these two points which I have here emphasised.

In a small manual written by Daguerre himself at this very time (1839), a copy of which we have in the Library of the British Museum, I find that the words used by Arago in his speech were these. He spoke of the invention as being a present "to the world of science and art." Historians have read this to mean the whole civilised world, whereas it is clear that Daguerre believed it to refer to the world of science and art in France alone. Had the French Government made it a clear condition that the gift must be extended to all nations, they would surely have insisted on this English patent being cancelled. Instead of that the patent became a source of income, presumably to Daguerre, for licences were granted for the use of this invention, as much as one thousand pounds being paid for the exclusive rights in some large towns. The patent did not expire till the regulation period of fourteen years had run out.

Following up these remarks which I have just made in Daguerre's defence, I can quite imagine some reader wishing to cross-examine me. If Daguerre believed that his agreement referred only to France, why did he take out a patent in England alone? Why did he not patent his process in America, in Germany, and other countries? I have no doubt that what induced Daguerre to take out a patent in England specially was that he was aware that he had an English rival in Henry Fox Talbot, of whom we shall read in the following chapter. Probably Daguerre believed Talbot's process to be similar to his own.

I quite admit that the course taken by Daguerre is difficult to account for, and I was not altogether surprised to come across the following sentence in an old pamphlet in the Library of Patents (London):[1] "M. Daguerre himself, very reluctantly, however, yielded to the wishes of his friends, and secured a patent in England, by taking an advantage in a peculiarity in the patent laws of that country, yet it has been said he often regretted it."

In support of Daguerre's character I would quote a few sentences from the Commission's report to the French Parliament regarding the proposed pensions. "From the first M. Daguerre perceived that the payment of a stipulated sum might give to the transaction the base character of a sale. The case was different with a pension. Reflections like these could not fail to present themselves to *a man of his exalted character*, and M. Daguerre decided on a pension." (The italics are mine.)

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[1] The *Ambrotype Manual*, by Burgess, N.Y., 1857.

CHAPTER III

A GREAT ENGLISH INVENTOR

How Talbot came to think of what we now call photography—His reasoning of the matter—His first experiments—The exposures required—Great hopes and a great disappointment—Another accidental discovery—Daguerreotype versus talbotype—Some of the original talbotypes still good to-day—A defect in the daguerreotypes—How photography got on to new lines—Scott-Archer's wet plates—Dry plates—A survival of the wet plate.

IN our imagination we have seen Niépce and Daguerre hard at work in France for many years, earnestly seeking to fix the image of the camera obscura. Did no British scientific enthusiast make a similar attempt? We are proud to claim some part, and a very important part, in the invention of photography. The English enthusiast was William Henry Fox Talbot, who was born in the first year of the nineteenth century. His maternal grandfather was the Earl of Ilchester, so that Talbot's early training was very different from that of Daguerre.

Talbot was educated at Harrow, and then proceeded to Cambridge, where he distinguished himself as a scholar. He devoted some time to politics, being a member of the House of Commons in the first Parliament after the passing of the Reform Bill. Scientific investigation was really much more to his liking, and after two years he retired from politics in order to devote his time to science.

Two of Fox-Talbot's Original Photographs

Fox-Talbot invented the method of taking negatives from which any number of positives may be produced. The photographs reproduced above were taken on paper negatives, which were waxed afterwards so that positives might be printed through them. The upper illustration was from life. The other was a copy of a French engraving. (See chap. iii.)

Talbot was not aware of the experiments made by Wedgwood and Sir Humphry Davy, although these experiments were made during his own childhood. How then did Talbot come to think of what we now call photography? It seems quite natural that Daguerre should have hit upon the idea, as he was an artist, and was accustomed to use the camera obscura for sketching. Talbot was not an artist, nor was he aware of Daguerre's idea. There was, however, a small optical instrument called a camera lucida, by which it was supposed that even those who were not artists might make pictures. No dark chamber was required, as with the camera obscura. The landscape was viewed through a four-sided glass prism, and an image of the view was seen upon the drawing paper, so that the would-be artist might make his picture by tracing out the detail with his pencil. It may be pointed out here that unless one viewed the paper through the prism there was no image seen at all upon the paper, whereas the image produced by the camera obscura was directly projected on to the paper, and could therefore be seen from any point. It will be clear that the camera lucida would not suggest to any one to try and fix the picture by chemical process, for the picture was practically an optical illusion; it was apparently seen upon a sheet of paper, upon which it did not really exist.

Talbot made an attempt to sketch the Lake of Como, in Italy, by means of a camera lucida, but he found it no easy task. When describing this futile attempt Talbot writes: "When the eye was removed from the prism—in which all looked beautiful—I found that the faithless pencil had only left traces on the paper melancholy to be-hold. I came to the conclusion that the instrument required a previous knowledge of drawing, which unfortunately I did not possess." It was Talbot's failure with the camera lucida which caused him to try the camera obscura. Here again he found that "it baffles the skill and patience of the amateur to trace all the minute details visible on the paper;[1] so that, in fact, he carries away with him little beyond a mere souvenir of the scene —which, however, certainly has its value when looked back to in long after years." Picture the amateur of today *pressing the button* and securing each time a beautiful souvenir of the place he is visiting. If we had not become so accustomed to photography, this would, indeed, read like a fairy tale.

The quotations I am making here are from Talbot's original work—*The Pencil of Nature*—which was published in 1844. He tells us there that it was "the inimitable beauty of the pictures of Nature's painting which the glass lens of the camera throws upon the paper in its focus—fairy pictures, creations of a moment, and destined as rapidly to fade away"—it was the beauty of these pictures which led him on towards the great goal which he ultimately reached. He reflected how very charming it would be if these pictures would but imprint themselves upon the paper. The thought was quite original in the mind of Talbot. He asked himself why should this entrapping of the picture in the camera obscura not be possible. His reasoning of the matter is very interesting. He argued that if you divest the

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[1] Talbot evidently placed a piece of tracing paper in the focus of the camera, this corresponding with our ground-glass screen.

picture of the ideas which accompany it, and consider only its ultimate nature, it is but a succession or variety of stronger lights thrown upon one part of the paper and of deeper shadows on another. He therefore thought the matter out in this fashion. Light can exert an action, and in certain circumstances it does exert one sufficient to cause actual changes in material bodies. If he could only prepare a paper in some manner so that it would be acted upon by light, and visibly changed by light falling upon it, might he not then hope that the variegated scene of light and shade would leave its image or impression behind?

At the time when these thoughts occurred to Talbot—in 1833—he happened to be on a visit to Italy, so that he could not conveniently make any experiments. However, he made a careful note of the matter, and of such experiments as he thought would be most likely to realise his ideal, if it were indeed possible. Although Talbot did not know at this time of the experiments made by Wedgwood and Davy, he had read in chemical books that the nitrate of silver was a substance peculiarly sensitive to the action of light, and from the outset Talbot seems to have builded his hopes upon this silver salt. The one fear he had was lest this action of light upon the silver nitrate might not be rapid enough for his purpose. He had no idea as to whether the action was a rapid or a slow one, and upon the rapidity of the action he felt his success would depend. If the action turned out to be a very sluggish one, then his whole idea might remain a mere philosophic dream.

On returning home, in 1834, Talbot hastened to put his theory to the test. Taking a sheet of white paper, he carefully brushed it over with a solution of nitrate of silver, and then exposed the prepared paper to sunlight. Alas! his hopes fell, for the action of the light proved to be very much slower than he had anticipated. Then he tried chloride of silver—it proved no better. However, instead of simply brushing the surface of the paper with a solution of chloride of silver, he tried to form the chloride on the paper. He first of all brushed the paper with a solution of common salt, the chemical name for which is chloride of sodium. He then brushed it over, when dry, with a solution of silver nitrate, which allowed chloride of silver to form on the paper. An exposure of this paper to sunshine seemed to give no better result. It so happened, however, that on one trial with paper prepared in this fashion Talbot observed that some parts of the paper blackened very much more quickly than others. These places seemed to be mostly around the edge of the paper, and with considerable patience he was able to analyse the cause. The most sensitive parts were apparently those which had been least wetted by the common salt. This could readily be proved. He tried a much weaker solution of salt, and then applied the silver nitrate. He was delighted to find the whole surface of the paper blacken uniformly and rapidly. Indeed, he found that too strong a solution of salt was so destructive of rapid change that he afterwards used salt to fix his pictures when taken. By washing them in a strong solution of common salt he was able to prevent any further chemical action.

Up to this point Talbot seems to have contented himself with simply exposing the prepared papers directly to sunlight. With this new paper he found it an easy matter to take an impression of any flat objects, such as leaves, lace, etc., by merely laying these objects upon the sensitised paper. No doubt many of us have recollections of amusing ourselves when children by making impressions of ferns, butterflies' wings, etc., by placing these objects in a photographic printing frame between a piece of clear glass and a piece of ordinary photographic paper.

Talbot would, doubtless, hasten to try his new paper in a camera obscura. The result was, however, very far short of what he had expected. Even when he exposed the paper for "a moderate space of time"—by which he meant an hour or so—"the outline of the roof and chimneys against the sky was marked enough; but the details of the architecture were feeble, and the parts in shade were left either blank or nearly so." It was evident he must seek some chemical preparation much more sensitive. It was many months before Talbot had an opportunity of experimenting, but in the interim he had, no doubt, given the subject much patient thought. I do not wish, however, to weary the reader with too much detail, and as the further experiments which Talbot made on this occasion did not enable him to reach his goal, I shall pass them over.

In the following summer (1835) this patient experimenter was able to improve matters considerably by giving his paper alternate washings of salt and silver, and then exposing the paper in a wet state in the camera obscura. By such means he was able to reduce the time of exposure to ten minutes on a bright day. However, his ideal seemed still very far from being attained, and for the next three years nothing further was done for want of sufficient leisure to experiment.

Hope was revived at the close of 1838, when Talbot hit upon an entirely new fact. In some earlier experiments he had used iodine to form iodide of silver on his paper, but the result was a failure. It so happened in 1838 that he had spread a piece of silver leaf on a pane of glass and thrown a particle of iodine upon it, whereupon he observed coloured rings form themselves on the silver around the particle of iodine. It was evident that these rings must be layers or films of iodide of silver. Talbot's astonishment was far greater when, on bringing the plate to the window, he found the rings to change colour and to assume unusual tints. It would be of interest to see if this effect was a lasting one, or if perchance some further change would take place, and so Talbot laid the plate aside for a time. We can see that Talbot was getting on to the very lines upon which Daguerre met with success—a silver surface treated with iodine. Whether or not Talbot's next experiment might have been on these lines can only be a matter of speculation, for at this point the plucky toiler got a sore disappointment. His hope of being the first to announce to the world the existence of a new art, which has since been named photography, was completely shattered. In the opening days of January, 1839, Daguerre's great discovery was made public. In the same month Talbot made his discovery known through the illustrious Michael Faraday, of electrical and chemical fame. Professor Faraday intimated the discovery at a meeting of the Royal Institution,

Negative and Positive

The upper illustration is a reproduction of the negative obtained by the camera. The lower illustration is of a photographic print from the same negative. Black and white in the negative appear white and black respectively in the positive. It will be observed that the right-hand of the negative is the left-hand of the positive. (See chap. iii.)

London, and a few days later the full details of the process were given, the communication being made under the title of "Photogenic Drawing." This communication was therefore made more than six months before Daguerre gave the details of his process to the public. The two processes were, of course, on quite different lines. In one direction Talbot's invention far surpassed that of Daguerre's: Talbot gave us a negative from which any number of copies might be made.

It was only shortly before this time that Talbot came to hear of the early experiments of Wedgwood and Davy. Talbot expressed great surprise that these interesting experiments had been allowed to fall into oblivion for practically a whole generation. However, there was nothing new for Talbot to learn from these experiments; he had already far surpassed them.

It will be remembered that Daguerre's success depended very much on the lucky "accident" of the magic cupboard. Some years later Talbot too was fortunate enough to fall in with an "accident" of a somewhat similar, though less romantic, nature. One of his exposed papers happened to come in contact with a solution of nut-galls (gallic acid), whereupon he found his picture to be vastly improved in detail. In this way it was found that a short exposure in the camera, producing only a latent or hidden image, could be developed by an application of gallic acid. The result which Talbot got from this latent image when developed was what we call a negative;[1] bright objects

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[1] It was Sir John Herschel who first used the words negative and positive in connection with photography. The photographic plate when developed is indeed a true negative—white being represented by black, and black by white.

appear as black, and shadows are represented by clear parts. (See illustration, facing p. 50.)

It turned out to be very convenient that the resulting picture was a negative, for it was possible to produce any number of positives by ordinary contact printing. It was necessary for Talbot to wax his paper negative to make it translucent. Sir John Herschel suggested the use of glass as a foundation for the sensitive chemicals, but it was found difficult to form the silver compounds on the glass.

Talbot named his new process *Calotype* (beautiful picture), but it was also called *Talbotype*, in honour of the inventor. Talbotype and daguerreotype were rival processes. One would expect to find that the professional photographers had preferred to practise the talbotype process, so that they might be able to give their patrons a number of copies of a photograph from one negative. However, it was not so: the majority of the professionals preferred the daguerreotype, despite its one copy only. This was probably because the detail in the daguerreotype was more perfect, and possibly because a portrait on a "silver plate" could command a larger price. Talbot's process was more popular among amateurs, because of its greater simplicity.

When Talbot published *The Pencil of Nature*, in 1844, he pasted original photographs into each copy. I thought it would be of interest to see how these original prints had stood the test of time, it being now more than the space of two generations since they were made. On examining the copy in the British Museum Library, I find that most of the pictures are badly faded. Another copy in the Euing Collection at the University of Glasgow happens to be in a much better state of preservation.

Looking down the list of illustrations, I was surprised to find "A Scene in a Library." Curious to see how Talbot managed an interior, I turned up the illustration, to find a photograph of two rows of books on shelves, presumably in an open book-case. Some of Talbot's pictures are splendid in detail; they are all of much interest. In showing a photograph of a haystack with a ladder leaning against it, Talbot remarks that no artist would trouble to reproduce all the detail given by the camera; it would indeed be impossible.

In the accompanying illustrations facing page 44 I have reproduced two of Talbot's original photographs, which he took himself some sixty-five years ago. These I have photographed from the copies pasted into *The Pencil of Nature* by Talbot. The upper illustration is entitled "The Ladder," and I think it will be of interest to reproduce Talbot's own article published along with this picture.

"Portraits of living persons and groups of figures form one of the most attractive subjects of photography, and I hope to present some of them to the Reader in the progress of the present work.

"When the sun shines, small portraits can be obtained by my process in one or two seconds, but large portraits require a somewhat longer time. When the weather is dark and cloudy, a corresponding allowance is necessary, and a greater demand is made upon the patience of the sitter. Groups of figures take no longer time to obtain than single figures would require, since the Camera depicts them all at once, however numerous they may be: but at present we cannot well succeed in this branch of the art without some previous concert and arrangement. If we proceed to the City, and attempt to take a picture of the moving multitude, we fail, for in a small fraction of a second they change their positions so much as to destroy the distinctness of the representation."

Then, referring to the possibility of taking family groups, Talbot adds: "What would not be the value to our English Nobility of such a record of their ancestors who lived a century ago? On how small a portion of their family picture galleries can they really rely with confidence?"

I observe that despite Talbot's remark in this article that he hoped to present a number of portraits with *The Pencil of Nature*, he has only one other picture containing persons, and that out of thirty-one photographs presented.

The lower illustration (p. 44) was a photograph taken by Talbot to show how engravings, etc., might be faithfully reproduced by photography. Little did Talbot think that the mechanical printing-press would, some day, reproduce this photograph of his by the thousand. I think I cannot do better than quote Talbot's own words concerning this photograph.

"We have here a copy of a Parisian caricature, which is probably well known to many of my readers.

"All kinds of engravings may be copied by photographic means; and this application of the art is a very important one, not only as producing in general nearly facsimile copies, but because it enables us at pleasure to alter the scale, and to make the copies as much larger or smaller than the originals as we may desire.

"The old method of altering the size of a design by means of a pantagraph, or some similar contrivance, was very tedious, whereas the photographic copies become larger or smaller, merely by placing the original nearer to or farther from the Camera.

"The present plate is an example of this useful application of the art, being a copy greatly diminished in size, yet preserving all the proportions of the original."

There was one defect in daguerreotypes which did not occur in Talbot's pictures. It will be observed in the left-hand illustration (p. 30), by the aid of a magnifying glass, that the letters on the base of the pedestal of the monument are printed backwards. Everything was reversed as far as right and left was concerned. It will be obvious that Talbot's negatives must have been similarly reversed, as is demonstrated by the ordinary negative shown facing page 50. This reversal on the negative is very convenient, for when we make a positive from it there is another reversal, and, as we all know, "two negatives make a positive." In looking at the illustration (p. 50) one must remember that the two pictures were lying face to face when taken from the printing frame.

In the centre of this photograph, which I have used to illustrate a negative and a positive, there will be seen a very high monument. This is a monument of Sir Walter Scott, and there is a strange story told concerning it. It is generally believed that the sculptor made a mistake in putting the plaid upon the right shoulder in place of the left, and that when this was pointed out to the sculptor he took his own life. There have been many debates concerning the truth of this story. Some writers have argued that the Lowland shepherd often wore his plaid upon the right shoulder. I have been in correspondence with two of the best authorities on such matters, and both agree that the sculptor made a mistake in placing the plaid upon the right shoulder. The latter part of the story, fortunately, is not correct. The sculptor did not take his own life when this was pointed out. He was dying of consumption all the time he was working at this monument, and he died before it was set up. My reason for mentioning this matter here is because I have sometimes wondered if this sculptor was led astray by some daguerreotype of a Highlander, in which the plaid would appear to be upon the right shoulder. I have beside me a daguerreotype of a monument of Perseus, in which he wields his sword with his left hand. There cannot have been any daguerreotypes of Sir Walter Scott himself, as the great author died just at the time when Daguerre was hard at work trying to fix the image in the camera obscura.

Although some photographic studios were opened in 1840, photographs remained curiosities till 1853. During the intervening time Daguerre's and Talbot's processes were rival ones, but both were to be totally eclipsed by a new process. Daguerre's English patent expired at this time, and Talbot's claim that the new process was an infringement of his calotype was defeated, so that the whole field was left free.

How did photography get on to new lines at this time? We do not associate the peaceable art of photography with the manufacture of deadly explosives, and yet there is an intimate connection at this point. A Swiss chemist had discovered that if ordinary cotton wool was immersed in a mixture of nitric and sulphuric acids, it became highly explosive. It was found to be many times more explosive than gunpowder, and it became known under the title of gun-cotton. A little later there was a substance produced by dissolving gun-cotton in a mixture of ether and alcohol. The resulting material was called collodion, being so named from its adhesive qualities. Collodion was very soon used in surgery to form a film over wounds and thus prevent contact with air.

Several scientists suggested that collodion might be used for holding the chemicals on the photographic plate. It remained, however, for a London sculptor—Frederick Scott-Archer—to bring these suggestions into practical form.[1] Archer had been using photography for taking pictures of his sculptures, but after bringing out his collodion process he set up a photographic business. His place of business was in the same street as that from which this book is being published—Great Russell Street, London. Archer made his process known in 1851, but he did not take out any patent. Unfortunately his inventions brought him no wealth, and after his death it was found necessary to assist his widow and children.

The collodion process quickly displaced daguerreotype and talbotype, and, indeed, made photography a popular

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[1] Scott-Archer's collodion process will be explained later in connection with the making of photo printing blocks, for which the wet collodion process is still used. The collodion not only acts as a support for the chemicals, but assists in the decomposing action of light.

art. It was necessary, however, that these collodion plates should be exposed in the camera while the chemicals were moist. A further disadvantage was that they had also to be developed before the chemicals dried. These disadvantages would, of course, not be so serious to the professional photographer in his studio. To the amateur or the professional desirous of taking landscapes, etc., the difficulties became greater. We have records of some early enthusiasts carrying their chemicals and a barrel of water up mountain sides and so on.

Some chemists succeeded in arranging the chemicals so that the plates might remain moist and sensitive for a week or more. A few years later it was found possible to make a plate which would remain sensitive when dry. Improvements in the making of dry plates soon followed. Gelatine was substituted for the more dangerous collodion, and the silver salts were dissolved in the gelatine. The pictures produced on the old-style wet collodion plates have, however, never been surpassed, and this process is still used for special purposes, as we shall see when we come to consider the making of book illustrations. Scott-Archer's collodion process may be said to form the basis upon which all present-day photographic plates are made.

We still have a survival of the wet-plate process at country shows, etc. We may enter the tent of the itinerant photographer, have our photographs taken, and handed to us in a few minutes. These pictures are on thin sheets of black or chocolate-coloured enamelled iron. The photographer can only give us one copy for each exposure. It is really a negative that is taken, and it is converted into a positive in the following manner.

By permission of *the Criminal Investigation Department, Glasgow*

EARLY PHOTOGRAPH OF CRIMINALS

The photograph from which this has been reproduced is one of Scott Archer's positives on glass. The inscription on the back of the little frame commences—"No. 1. James Martin Lindsay. Dirty thief."
(See chap. xi.)

During the process of development some chemicals are added to make the film remaining upon the plate white instead of black, as it would otherwise be. Then where there is no film remaining the black enamelled plate is seen. In this way a negative is transformed into a positive. These pictures have been called *tintypes*, or by some people "tin photographs." One occasionally finds at international exhibitions some ingenious automatic machines which take photographs upon this tintype principle. These tintypes are merely an application of Scott-Archer's process, and, indeed, the inventor himself very often transformed his glass negatives into positives. During development he whitened the black film, and then, in order to convert the transparent parts into black, he painted the back of the glass plate with black varnish, thus making the negative a positive. This, however, was of small importance compared to the larger use of the plate as a negative from which any number of positive prints might be produced on photographic paper.

One occasionally comes across specimens of these glass positives at the present day. Indeed, when I set about making inquiries for some good daguerreotypes, with the object of reproducing them in the present volume, I was repeatedly offered "good daguerreotypes" which turned out to be glass positives made on Scott-Archer's plan. The illustration shown facing page 58 is a photograph of one of these glass positives. I merely remark this in passing, as my object in showing this illustration is its connection with the photographing of criminals. The illustrations facing page 30 are from real daguerreotypes, and these are by far the best specimens I have been able to find.

CHAPTER IV

INSTANTANEOUS PHOTOGRAPHY

A really trying ordeal—Were the early portraits "speaking likenesses"?—More about Arago's speech—A London science lecturer's discovery—The origin of *cartes-de-visite*—An interesting experiment at the Royal Institution—Photographing by the light from an electric spark—Instantaneous shutters—Photographing animals in motion—The Zoetrope suggests the cinematograph—Great scenes lived over again—How the photographs are taken and the pictures reproduced—The cinematograph in the future.

SOME of us still consider it quite an ordeal to have our photographs taken professionally, but what should we have said had our experience been that of one of the first victims? Imagine the photographer calmly painting your face white, while he informed you that the flesh did not reflect sufficient light to affect the chemicals on his photographic plate. Even that trial would sink into insignificance when you were boldly informed that you must sit perfectly still for about twenty minutes. The tormentor was merciful enough to allow the sitter to keep his or her eyes closed. Indeed this was a necessity, for the full sunlight was to be reflected on to the face. The photographer seems to have had some passing thought of his patient's comfort, for he passed the sunlight through a glass tank containing a solution of blue-stone (copper sulphate) in order to absorb the heat rays.

During the twenty minutes—it would seem like hours—through which the painted subject sat motionless, the photographer seems to have busied himself arranging that any white parts of the dress did not remain too long exposed to the light. He was mindful of what he termed "temporary expedients."[1] For instance, his instructions were: "A person dressed in a black coat and open waistcoat of the same colour must put on a temporary front of a drab or flesh colour, or, by the time that his face and the fine shadows of his woollen clothing are evolved, his shirt will be solarised, and be blue, or even black, with a white halo around it."[2]

If we picture the poor sitter with white face and closed eyes, we cannot imagine that the resulting picture would be a "speaking likeness." I fancy these first portraits must have been rather suggestive of *some dear departed friend*, and one is not surprised to find among the instructions that "the hands should never rest upon the chest," although the reason assigned for this is that "the motion

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[1] The quotations regarding these early attempts at portraiture will be found in the *London and Edinburgh Philosophical Magazine* for September, 1840. These early portraits were taken by Dr. Draper, of New York, and while he found twenty minutes' exposure necessary, it is asserted by a relative of the gentleman, who was the first to be photographed by Daguerre himself, that the old gentleman had to undergo the trying ordeal of one hour's exposure in sunlight. Imagine sitting motionless for the space of one hour to have one's photograph taken!

[2] This question of *solarisation* has been of interest from the earliest days of photography. The chemistry of the subject is beyond the scope of this book, but it may be stated that solarisation is destruction of the image by over-exposure, followed by reversal of the image. In this way the image of the white shirt on the daguerreotype becomes very white and then gradually turns darker and ultimately appears black.

of respiration disturbs them so much as to bring them out of a thick and clumsy appearance, destroying all the representation of the veins on the back, which, if they are held motionless, are copied with surprising beauty."

Despite the remark I have just made, that the portraits cannot have been "speaking likenesses," it is quite evident that the photographer did aim at having his pictures true to life. In the description of a special chair arranged with a staff, terminating in an iron ring, for supporting the head, I find the following note: "By simply resting the back or side of the head against this ring, it may be kept sufficiently still to allow the minutest marks on the face to be copied." It is obvious that there was to be no retouching. How far we have fallen away from this ideal may be judged by the following incident. A lady, having had her photograph taken by one of our leading photographers, handed a copy of it to a lady friend. The friend admired it; "Simply charming, it is quite a picture; but do I know the lady?"

The early attempts at portraiture, to which I have referred, were made in New York by the daguerreotype process. This process was more widely used in America than in Great Britain. I wonder what the early photographer would have said had one of his sitters suggested that photographs should be taken instantaneously. No doubt he would have replied that such a thing would be an utter impossibility.

In connection with the modern facilities for amateurs taking instantaneous photographs—or snapshots—it is of interest to note the following sentence, which is taken from M. Arago's address to the Chamber of Deputies, when claiming a pension for Daguerre and Niépce. Speaking of the time required to take a photograph by Daguerre's process, he mentions from about half to three-quarters of an hour; he then adds the following: "Those persons are deceived, then, who suppose that during a journey they may avail themselves of brief intervals while the carriage slowly mounts a hill to take views of a country." The amateur may now *snap off* a dozen photographs in a few minutes, while he walks or drives. It should be noted that when Arago mentioned from a half to three-quarters of an hour, he did not refer to the time of exposure alone, but to the time spent in preparing the plate, adjusting the camera, and finally developing the image, these operations having to be performed on the spot.

Referring again to that part in Arago's speech where he said that a slight advance on the progress Daguerre had then made would enable him to execute portraits from life, I have already pointed out that the necessary improvement was made by an Englishman. It was a science lecturer in London, John Frederick Goddard, who found a means of making the plate sufficiently sensitive for this purpose. He accomplished it in this wise. Taking one of the daguerreotype plates which had been exposed to the vapour of iodine in the regulation manner, he further exposed it to the vapour of bromine, a non-metallic element whose name signifies a disagreeable odour (Greek *bromos*). Goddard found that the plate thus treated was rendered so sensitive to light that an exposure of twenty seconds was as effective as an exposure of as many minutes on Daguerre's ordinary plates. Here indeed was an immense improvement, which was accomplished in the year 1840, just about twelve months after Arago's eloquent address to the French Chamber of Deputies. Photographic studios were soon opened in all large cities, and the well-to-do citizens willingly paid as much as six guineas for a single daguerreotype portrait. Alas! their descendants have treated many of these fine works of art with scant respect, having often given them as playthings to children. The early attempts at portraiture in America, already referred to, were, of course, prior to this discovery of Goddard's.

There is one term in connection with portraits which has an interesting origin. We are no doubt all familiar with that size of portrait which is called *carte-de-visite*, although one does not hear of it so often now; larger photographs being more common. The old portrait albums were made to hold these small *cartes-de-visite*, and I can remember, when a boy, wondering at so curious a name. There seemed to be no possible connection between these portraits and visiting cards, and yet there was an intimate connection originally. In the year 1857 the Duke of Parma had his portrait gummed on his visiting card in place of his name. The photographer to the Court of Napoleon III brought this idea into fashion in Parisian society, so that every person presented his friends with his *carte-de-visite*. No doubt these original portraits were somewhat smaller than those we remember under this title.

Our English inventor, Henry Fox Talbot, made a very interesting experiment in instantaneous photography as early as 1851. This he performed at a meeting of the Royal Institution (London), and afterwards gave an account of it in the *Athenæum*, December 6, 1851.

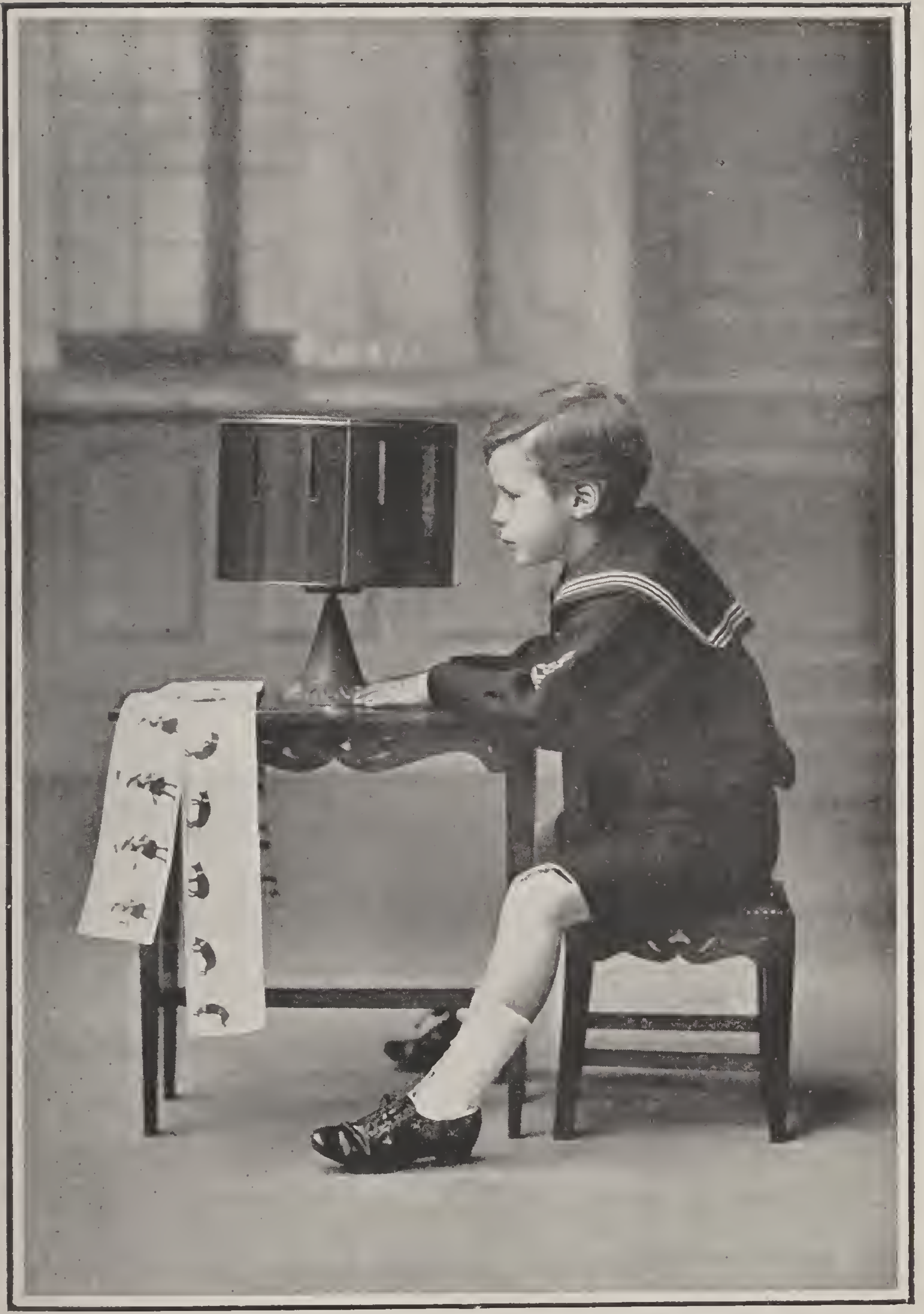

Photo by *R. Brinkley and Son, Glasgow*

THE ZOETROPE

This ingenious toy, which is perhaps better known as the wheel of life, was the forerunner of the cinematograph. The arrangement of the pictures will be seen from those lying upon the table. (See chap. iv.)

Taking a newspaper, he fastened it to the edge of a wheel, which was then set in rapid motion. The lights in the lecture hall were put out, the lens of the camera left open in the dark, and then a momentary illumination produced by the spark from a battery of leyden jars. The photographic plate was immediately developed, and it was found that a faithful picture of the printed newspaper had been produced—"not even a letter being indistinct." This showed the specially prepared plate to be extremely sensitive. I wonder if it ever occurred to any of the many scientists present that the revolving wheel was, logically, only a stage effect. I do not suggest that Talbot intended it to be so, but if one considers the fact that the total period of illumination obtained from the electric spark was somewhere between one ten-thousandth and one millionth part of a second, it was surely immaterial whether the wheel was revolving or standing still.

Some years ago Professor C. V. Boys photographed flying bullets by means of an electric spark. His experiments will be described in a later chapter. One French scientist has taken a number of consecutive photographs of flying insects, using an electric spark as the source of light. In this case the experimenter used magnesium electrodes, between which the electric spark occurred, and this seems to have greatly increased the amount of available light, for the prints which I have seen of some of these flying insects are splendidly illuminated.

Talbot's instantaneous process was too complex to prove of practical value; no one but the inventor himself ever succeeded in getting satisfactory results. Daguerre also invented an instantaneous process which proved too complex and uncertain.

The late Lord Armstrong obtained many beautiful photographs of electric sparks, causing them to depict their own images directly on to photographic plates; these were, of course, produced without a camera. I have already reproduced some of those autographs of the electric spark in *Electricity of To-day.*

Before the days of instantaneous photography, one scientist used the zoetrope to enable him to reproduce animal locomotion. This instrument may be better known to some readers under the title "wheel of life." A boy is seen using the instrument in the illustration facing page 64. A number of pictures are painted, in succession, on a long strip of paper. The first picture may be of a boy about to jump, while in the second picture he is seen just leaving the ground; in the third picture he is in the air, and so on each picture goes until he has returned to the position in which he was at first. When this strip of paper is revolved in a cylinder and viewed through small open slits, one sees the pictures following each other so quickly that the boy really seems to be in motion, although his movements are somewhat spasmodic.

An ingenious photographer arranged a whole battery of cameras, with which he took a number of photographs in quick succession of a horse in motion. He afterwards threw these photographs, very quickly after one another, upon a magic-lantern screen, and was, in this way, able to "reproduce the visual appearance of horses trotting, etc."

These experiments must have suggested, to many people, the idea of producing more perfect animated pictures. While we have in the Patent Office the record of one invention for this purpose—as far back as 1889—it was left to the great genius of Edison to place a practicable apparatus upon the market, some three years later.

I wonder what our grandfathers would have said, had they been present at some magic-lantern entertainment, when suddenly a man in one of the pictures began to move and to walk to and fro. Possibly they would have doubted their senses, or questioned whether they were waking or dreaming. A door in the picture opens, and in walks a second man, shakes hands with the first moving figure, and so on. How marvellous all this would have seemed to our grandfathers, and yet how soon do we forget the romance of the subject!

Some great ceremony takes place one afternoon, and on the evening of the same day thousands of people see the very same scene most faithfully reproduced by the cinematograph upon a lantern screen. The hero of the hour repeats every movement and gesture. The audience have an actual view of the ceremony, which is far more impressive than the clever word pictures of our journalists.

First of all we had the *kinetoscope* from Edison. This instrument was after the style of the old-fashioned stereoscope boxes, and one person at a time looked through the eyepieces at the moving pictures. The photographs followed each other in rapid succession, the pictures being upon a long ribbon, as will be described a little later.

A few years after the arrival of Edison's kinetoscope there appeared the cinematograph, by Lumière, of Paris, and also the American biograph. I only propose to mention the general principle upon which such instruments work; it is the photographic part which interests us at present.

There is first of all the taking of the photographs. To get a really satisfactory result it was found necessary to take successive photographs at a rate of nearly one thousand per minute. It is generally believed that the speed is forty-six per second (2760 per minute), but I find that in reality the speed is only one third of that stated. The speed, however, will vary with different operators, and no doubt at times with the variation of subject, but for our present purpose we shall reckon the speed to be fifteen pictures per second.

If photography had been confined to glass plates, the cinematograph would have been an impossible thing. Imagine trying to pass 1000 glass plates through a camera or a magic lantern in one minute! The introduction of flexible celluloid films made it possible, for the sensitised film could then be made in the form of a long ribbon. It is, of course, necessary to make the pictures very small, as they have to follow each other so rapidly. The accompanying photograph shows the actual size of the pictures (see facing p. 70). The progressive motions of the figures in the pictures will also be seen by comparing the succeeding pictures.

If 1000 exposures have to be taken in the camera every minute, it is clear that the speed must be great. Considering the smallness of the pictures, however, one finds by simple calculation that the speed of the film is not much more than half a mile per hour, which is about eight times slower than an ordinary walking pace.

But while this is the rate at which the film passes through the camera, we must bear in mind that the motion given to the film is not a simple gliding one. I shall speak of each part of the film receiving a picture as *a film.* Each film has about one fifteenth part of a second in which to pass the lens, but it must not glide past. It must jump quickly into position and remain at rest for about nine-tenths of its allotted span, in order to receive the latent image. We may therefore picture the film resting for about three fiftieths of a second, and making its jump forward in about $\frac{1}{150}$th of a second. This means that the film must be jerked forward into position at a speed of about six miles per hour.

The cinematograph films are wound upon brass drums, having very deep flanges, and one of these with a long film has considerable weight. Now we know that all bodies are very lazy about starting into motion, and equally lazy about stopping. This property of matter we call *inertia.* The greater the mass of the object, the greater the inertia. It will therefore be inconvenient to suddenly start and stop this drum carrying the long film. This difficulty is overcome by keeping the drum revolving constantly at the speed at which the whole film has to pass through the camera. Then a loose loop of the film is arranged between two sets of feed rollers. The particular part passing between these rollers is alone given the sudden jerky motion. That is to say, the bulk of the film is travelling at a steady pace, but each portion as it comes between these feed rollers is jerked into position before the lens, an exposure made, again jerked away from the lens, and then proceeds again upon its even course, to be finally rolled around another deeply flanged drum.

When the long ribbon film is developed, a positive ribbon is produced from this negative, in the same way as one makes ordinary magic-lantern slides. Some films have been made so long that it takes an hour to show them upon the screen, so that these films must have contained about 55,000 pictures. Indeed, it is very possible that the number considerably exceeds this, for it is apparent that the pictures are reproduced at a greater speed than that at which they were taken. Every one seems to be in a great hurry. Instead of quietly walking across a street, a man seems to be practising for a walking race. This quicker movement is, of course, no disadvantage in reproducing a horse race or any rapidly moving body, but I always think that our cinematograph friends make a mistake in rushing through the films where ordinary rates of locomotion are concerned. Thinking that there could be no optical advantage in this quicker movement, I inquired of one of the operators the reason for this increased speed. When I put a simple inquiry as to the rate at which the pictures were taken and the rate at which they were reproduced, he, at first, said they were at the same rate. When I pointed out that every one in the pictures was very energetic, he agreed that the pictures were being reproduced quicker, and the only reason was that he had to get through so many films in a certain time. He also agreed that if the orchestra were playing quick music the cinematograph operator was very apt to go quicker in sympathy with the music.

The Cinematograph and Biograph Companies have been

By permission of *John Trotter, Glasgow*

CINEMATOGRAPH PICTURES.

The whole of these photographs will pass through the cinematograph in less than one and a half seconds. A subject with a very quick movement has been selected, as otherwise the difference between the successive pictures would be scarcely observable. Observe the right hand falling in the last row of pictures. (See chap. iv.)

most enterprising. They have sent representatives to all parts of the world. While these exhibitions cannot fail to fascinate us, how much greater would our interest be if we could see some of the stirring scenes of past centuries lived over again before our very eyes! When the present generations of men have all passed away from the stage of life, our distant descendants may be able still to see our great ceremonies, or incidents in our great battles. In this sense the cinematograph does for sight very much the same as the phonograph does for sound. We can bottle up our living scenes just as we may store up the songs of our great singers. When are such romances to end?

CHAPTER V

CAN WE PHOTOGRAPH IN COLOURS?

An early speech concerning colour photography—What is colour?—A rather Irish explanation—A lesson from soap-bubbles—Whence the colours come—Our total stock of colour—Why a spectrum is formed—What the painter really does—The problem of colour photography—Taking the photographs—A simple illustration—Recording compound colours—Reproducing the coloured picture—A seeming roundabout performance—Can we call this "colour photography"?—A small instrument with a very long name—Why some people are disappointed with Ives' process—Coloured pigments—Why call green a primary colour?—The difference between mixing coloured lights and coloured pigments—A summary of Ives' process—How red rays affect the plate.

WHEN Talbot spoke of fixing the image of the camera obscura, he seems to have taken it for granted that every one understood that there was no fixing of the natural colours, but merely a black and white image. On the other hand, when the report upon Daguerre's process was read before the Chamber of Peers (France), this matter was dealt with in the following words: "We hasten, however, to explain, without wishing in aught to lessen the merit of this beautiful invention, that the palette of the painter is not very rich in colour—black and white compose the whole. The image in its natural and varied colours may remain long—perhaps for ever—a thing hidden from human sagacity. But let us not rashly circumscribe knowledge within impassable bournes. The successful efforts of M. Daguerre have disclosed a new order of things."

Photography in black and white is certainly a wonderful invention, and has proved most useful in almost every walk in life. From an artistic point of view it would be a very much greater invention could we but fix the natural colours, just as we see them upon the ground-glass focussing screen of the camera. To fix the image in black and white is comparatively easy, for the picture on our photographic plate only requires to be made up, as it were, of something and nothing and a mixture of something and nothing. That is to say, some parts of the negative have a dark film remaining, while other parts have nothing, leaving the clear glass transparent, and the remaining parts of the picture come somewhere between the dark solid film and transparency. In this way we obtain all the variety of light and shade.

When Talbot was reasoning out the possibility of fixing the image of the camera obscura, he said that the picture, divested of the ideas which accompany it, is merely a succession of stronger lights and deeper shadows. He seems to have included the sensation of colour as one of the ideas which accompany the picture. The fact remains that on the ground-glass focussing screen of the camera there is a picture in all its wealth of natural colours, while on our photographic plate and paper print there is nothing to stimulate our sensations of colour. Clearly to understand wherein the difference of these two pictures exists we must form a correct notion of what colour is.

To say that colour is not a material thing is true and yet misleading; colour is not merely an idea. One often finds this subject to be a stumbling-block to the young mind. For instance, I remember this colour difficulty being brought up by some schoolgirls who had just returned home from a first-class boarding-school. They informed me that their teacher had told them that colours did not really exist at all; that if the girls could only see their dresses when hanging up in the dark wardrobe, they would find that the dresses had no colour. The illustration, as related by the girls, was certainly rather Irish, and reminds one of the poor Irishman who said he had nothing left in his wardrobe but the armhole of an old waistcoat. The girls naturally reasoned the matter in the following manner. If there is no "red stuff" put into a dress by the dyer, then how does everybody see it red; it is utter nonsense to say that colour does not exist. Or again, when the painter paints a railing green, surely he puts some "green stuff" on the railing. If not, where do the colours come from?

One or two simple experiments always help to make this question of colour quite clear to the young inquirer. We take a clay pipe and some soap-suds over to the window where we have good light. While we amuse ourselves blowing bubbles, we watch the largest ones, and we see that they are beautifully coloured, and that the colours keep changing. At one moment we see the bubble a beautiful red, then it changes to orange, green, and blue, and indeed at times it gives quite a rainbow effect. We know that this beautifully coloured bubble consists merely of some air enclosed in a thin envelope or film of soap and water. From whence then come the colours? They must come from the ordinary daylight which is falling upon the bubble; the light must contain all these different colours. The sun shines into a room and the light strikes some cut-glass ornament, whereupon we find a beautiful patch of rainbow colours reflected upon the floor.

Our next experiment requires an ordinary glass prism, which is simply a triangular piece of solid glass. In order to see this experiment to its best advantage we close the window-shutters and allow only a beam of bright light to enter the room. We then cause the beam of light to pass through the glass prism, whereupon we find the white light divides itself up into beautiful bands of different colours. At the one end we find a band of red, which blends into a neighbouring band of orange, and that into yellow, then follows green, next blue and indigo, and at the end a band of violet. When light is thus divided, analysed, or split up into its component colours, we call the resulting colour band a *spectrum*.

I was very much interested the other day when a little fellow of five years of age asked me if I knew that red and blue made purple. When I asked him who had told him this, he explained that no one had told him, but that he had been looking at a piece of blue cloth through a little red glass tumbler which he had in his nursery, and he saw the cloth became purple. I told him he was quite right, and that if he took notice of what he saw in that way he would find a great deal of interest all around him. The little fellow was quite amused to learn that the colours really come out of ordinary light, and that all colours can be made by mixing three primary colours—*red*, *green*, and *violet*.

In the spectrum of sunlight, more often spoken of as the solar spectrum, we find not only these three primary colours, but orange and yellow, occurring between the red and green. Then between the green and the violet we see blue and indigo colours.

It so happens that as far as our colour sensation is concerned we can produce orange and yellow by blending red and green lights together, and we can produce blue and indigo by blending green and violet lights together, so we may say that our whole stock of colour is *red*, *green*, and *violet*. If we have three lights of these colours we may produce every other variety of colour. I shall therefore speak quite freely of red, green, and violet as our sum total of colour.

We have seen the glass prism analyse sunlight and display the wealth of colour of which it is composed, but how does a simple piece of triangular glass manage to do this? It is difficult to find any very helpful analogy. If, however, we remember that each colour is a series of waves or vibrations in the ether,[1] and that the difference between one colour and another is merely caused by the different rates at which the ether is vibrating, we may then form some conception of what happens in the prism. The ether may be vibrating with such a comparatively slow to-and-fro swing that it does not affect the sensitive

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[1] The ether of space has no connection whatever with the liquid ether which is used as an anæsthetic. No one knows what the ether of space is, but it is not ordinary matter. It is a mysterious something which pervades all space and acts as a medium for transmitting light, etc.

retina of the eye at all, but we find a heating effect in such rays. When the rate of ether vibrations reaches a certain pitch they set up the sensation which we call *red.* If the rate of vibration is somewhat increased the resulting sensation is *green*, and with a still further increase of vibrating rate we have *violet.* If the rate of vibration be increased still higher, the rays fail to affect our eyes, but these invisible rays will affect a photographic plate.

When our red, green, and violet sensations are simultaneously excited, we have the effect of white light. Now when this white light falls upon a glass prism, the rays all meet with a certain obstruction. We may picture those rays with a slow rate of vibration (red) being deflected or *refracted* only a little out of their path when passing through the prism. The other rays (green and violet) are banging about, as it were, more energetically, and therefore suffer a greater degree of refraction, according to the rate of their vibrations. We therefore find the rays of different rates of vibration coming out at the other side of the prism at different angles. If we allow them to fall upon a sheet of white paper, we find the red rays are least bent out of their normal path, but the green rays being bent further fall clear of these, so that we have the red sensation stimulated by one set of rays and the green sensation separately excited, while an overlapping of the two sensations produces the effect of orange and yellow. Then again the violet is more bent out of its normal path than the green, so that it falls clear of the green, and the rays from that part of the paper excite the violet sensation. Here again there is an intermediate part of the paper upon which rays fall which excite both the green and the violet sensations, producing the sensations we know as blue and indigo.

Now it will be clear to us that if we only allow red rays of light to fall upon a piece of white paper or any other white object, that object will appear red, as it will only reflect red rays to our eyes. The colour is not part and parcel of the object. But there is another way of producing the same effect. We may apply certain chemical pigments to the surface of the paper or other object, so that when ordinary light falls upon it all the coloured rays are absorbed or blotted out with the exception of the red rays. The object only sends back red rays, and we again see the object red. Here again the colour is not part of the object, as we shall see by a very simple experiment. For the present we must be content to know that some chemical pigments absorb certain colour rays and send back the remainder, and that with the aid of sufficient variety of pigments we may so manipulate white light that we can produce every known colour. The question of colour absorption and reflection will be better understood when we come to consider *Nature's camera.*

Let us take some very red object—a pure red—say the chemical known as bin-iodide of mercury, which has a bright vermilion colour. There is no mistaking the fact that this substance is red. We have a quantity of this in a glass tube or bottle, but we must be careful to have it well corked up, as the substance is very poisonous. We close the window-shutters and set a light to some methylated spirits and common salt, which we have previously mixed in a small saucer. We now look at the red substance by this light, but, alas, it is no longer red; it is a dirty grey. Its beauty has quite forsaken it. We extinguish the artificial light and again view the substance by daylight—or by gaslight—whereupon its rich vermilion colour at once returns to it. Now it is quite clear no chemical change whatever took place in the red substance; it was securely corked up in a glass tube or bottle. Why, then, did the bright red colour disappear when viewed by the methylated spirits light? Simply because there are no red rays in that particular light, which is not white, but yellow, and contains scarcely any but yellow rays. The chemical is capable of reflecting red rays, but it is helpless if no red rays fall upon it. I have merely selected this particular chemical by way of illustration, as I find that it answers the experiment very well. We might use the red cover of a book, but it is difficult to get a pure red in which there is no mixture of other colours.

When the painter makes our railing green, what he really does is to put on some substance which will send back the green rays contained in white light and absorb the other rays. The limelight operator at the pantomime may change the colours of a dancer's dress, so that at one moment it appears red, at another green, or yellow, or blue. When he puts a red glass into the lantern he cuts off the green and violet rays, and allows only the red rays to pass out and fall upon the dancer's dress. It must surely be clear to every reader that colour is not an inherent property of the object.

I have purposely gone into the subject of colour at some length, for I do not think it possible for any one to form a comprehensive idea of colour photography without first obtaining a clear understanding of what colours really are. There is a wide field of interest in connection with colour; I have only touched upon the simple phenomena relating to our present subject.

It occurs to me that some reader may be wondering how the soap-bubble, already referred to, is able to produce different colours. This will be better explained a little later when we come to consider the Lippmann process of colour photography, which is based upon the same phenomenon.

Our problem is to entrap the colours as they fall upon the photographic plate. When we look at the image on the ground-glass focussing screen of a camera we see all the natural colours of the scene depicted there. We know very well that the ground-glass screen has no selective power for colours; it is merely reflecting whatever rays fall upon it from the different objects. It is the objects themselves which have split up the white light falling upon them and reflected back certain rays. How are we to fix these when we substitute a photographic plate for the focussing screen?

What a variety of different colours we are to entrap! The little five-year-old fellow reminds us that we have only three colour sensations—red, green, and violet; that all the other colours in the picture are produced by different mixtures of these lights. Ah! here then is one way of reproducing all this varied scene of colour. Let us first of all make the red rays alone enter the camera, and we shall get a negative which will be blank everywhere except where the red rays have fallen. Suppose by way of simple illustration that we are photographing a red vase containing some yellow flowers and green leaves. We wish first of all to take a record of all the red in the objects. We must let the red rays alone enter the camera. How can we do this? We know that a red object will reflect only red rays and absorb or cut off all the other rates of vibration. If the red object be transparent, say a piece of red glass, then it will not reflect all the red rays as an opaque body will do, but will let some of the red rays pass through it. Therefore if we take a piece of red glass, or better still a sheet of gelatine dyed a pure red, and place this so that all the light entering the camera must pass through this red screen, what will happen? The red screen will act as a filter to the light; it will absorb or cut off all the green and violet rays, and allow only the red rays to reach the photographic plate. It is immaterial whether we place this red screen of gelatine before or behind the lens, or right inside the camera directly in front of the photographic plate; all that we require is that the screen should intercept all the green and violet rays before they can reach the sensitised plate.

So far we have only made a negative showing the red objects. If we examine it we shall find that we have not only an image of the red vase, but also an image of the yellow flowers. That is to say, we have a record not only of the objects which appeared red, but of all the red rays, whether they were seen as red or blended together with some other rays, producing a mixed or compound colour. This is quite as we should expect, for we know that yellow is obtained by an overlapping or blending together of red and green.

If we now take a second negative, through a green colour screen, we shall have a record of all the green rays—the green leaves and also a fainter image of the yellow flowers again, as there will be green rays reflected by them. It will be understood that these are ordinary black and white negatives showing no colour. On the first negative we have an image of the red vase, and an image of the yellow flowers, but no image of the green leaves. On the second plate we find no vase, an image of the green leaves, and an image of the yellow flowers. The yellow flowers have affected both plates, as they reflected a mixture of red and green rays.

So far we have been speaking of the red vase as though it were a plain red one, but let us suppose that it is of some Eastern style and has a blue figure upon it. We know that blue is a blending together of green and violet, so that there will be an image of the blue figure upon the second or green negative. To entrap the remaining violet rays we must take a third negative, and this time through a violet screen. On this third negative we shall only get an image of the blue figure on the vase.

We have three different records, but we have no colours. We have, however, analysed our coloured objects; we have split up all the colours, taking a record of each primary colour upon a separate negative. Suppose we try and reconstruct our coloured picture. Perhaps the simplest plan will be to make a picture on the magic-lantern screen.

So far we have only made negatives. Now we must make lantern slides in the usual way. The reason for this will be apparent, for if we look at the first or "red"

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TWO INSTANTANEOUS PHOTOGRAPHS

The upper illustration is of a disused chimney-stack being demolished. The falling chimney appears to be stationary in mid-air, having been photographed in one-hundredth part of a second by means of a Thornton-Pickard focal-plane shutter. The lower illustration shows the attitude of a cock when crowing, and was taken in one-eightieth part of a second by means of a Thornton-Pickard time and instantaneous shutter.

negative, we find an opaque image of the vase upon a transparent background. This is just the reverse of what we want for the lantern, so we take this negative and print a positive from it. Instead of printing a positive on to photographic paper, we place a second photographic plate behind the negative. We simply make a contact print from the negative on to the second plate, so that the dark opaque vase will now be a transparent vase upon an opaque background. This is just what we want for the lantern.

If we now place this transparency or lantern slide in the magic lantern, we get a bright white image of the vase and flowers upon an otherwise dark sheet. If, however, we place a piece of red glass in the lantern, so that only the red rays of its light can pass out, we shall then have a red vase upon the lantern sheet. We shall also have a red image of the flowers in the vase. This red represents the amount of red which was reflected by the yellow flowers.

What I have just described is a reproduction from the first or red negative which we took, but it will be remembered that we afterwards changed our vase for a fancy one having a blue figure upon it. We made the green and violet negatives from this fancy vase, but I purposely left the red negative alone for the sake of simplicity. It will be quite apparent that if the fancy vase had been used for the red negative, then the blue figure would have reflected no red rays; and as there were only red rays entering the camera, we should now have on our transparency or lantern slide no light on that part of the vase representing the blue figure. I think the best way to look at the complete reproduction from the red transparency is this. Upon a dark background we have a red vase with the background showing through where the blue figuring should be; we have also red flowers representing the yellow flowers placed in the vase.

In the meantime lantern slides have been prepared from the green and violet negatives which we took. We must throw a green and a violet light respectively through these transparencies. We have practically three different lanterns, one for each colour. Each lantern will throw upon the screen its own particular part of the picture; it will therefore be very necessary to have all three lanterns carefully focussed so that the three pictures exactly overlap each other.

To continue the building up of our picture, we take our second transparency and throw a green light through it. This will add the green leaves, and also an image of the flowers in green, which, falling upon the faint red flowers, will make them appear yellow. Red and green lights overlapping produce the sensation of yellow. This fact will be easily remembered if one thinks of the colours in the solar spectrum; between the red and the green comes yellow.

Our green transparency has added something more to the picture. There is now a green image of the figuring upon the fancy vase. All that remains for the violet transparency to do is to throw a violet image of the figuring upon the vase, and this overlapping the already green image changes it to blue as in the original vase. Think again of the colours in the solar spectrum: between the green and the violet comes blue. For any one not quite conversant with the colours in the spectrum of daylight, it would be a good plan to paint the colours roughly upon a strip of white paper. Almost any child's paint-box would serve the purpose quite well. Make the red, green, and violet more prominent than the others, and then fill in orange and yellow between the red and green, and paint in blue and indigo between the green and the violet. If there is no paint-box conveniently at hand, it will be sufficient to write down the names of the colours in their proper positions; make the words red, green, and violet much more prominent than the others. If this strip of paper is kept as a book-mark it will be found very useful in reading the next chapter.

Looking at the lantern sheet, we now see our complete picture, the red vase with its blue figuring, the green leaves, and the yellow flowers. What a roundabout way we have taken of arriving at a reproduction of our picture! Why not have merely taken one single negative in black and white and then have coloured it? This suggestion only arises because I have chosen an ideally simple illustration. I have presumed the green leaves to be one uniform shade of green, and the same with the other colours. Think rather of some scene in a conservatory—an indescribable variety of shades in leaves and flowers. Our three negatives will record the component parts of all these shades, and we shall be able to reproduce these in all their delicacy far better than the artist can.

Can we call this result a photograph in natural colours? The "man in the street" says we cannot. The scientist may say, with some truth, that we have reproduced the natural colours; we made red rays record themselves, and we made that record to control the red rays once more. Have we not reproduced colour vision just as much as the phonograph reproduces sound? What the public really mean by colour photography is that the photograph, when viewed as an ordinary picture, should show the natural colours. We have not accomplished this.

The three-colour process, which we have been considering, was devised by Frederick Ives, of Philadelphia, about the year 1895. The colour photographs can be shown not only upon a large lantern sheet, they may be viewed in a small instrument which is burdened with a very long name—the stereophotochromoscope. This is a very ingenious little instrument, which does practically the same as the three-lens lantern, but in a portable form. Inside the small box the three-colour pictures are so arranged that they appear as one picture when viewed through the two eyepieces. The natural appearance of the picture produced in this long-named little instrument is enhanced by there being three pairs of slides, each pair producing a stereoscopic effect. We need not consider this part of the subject at present, as the principle of the stereoscope will be fully dealt with in a later chapter.

I remember seeing the first stereophotochromoscope brought to this country, and the effects produced were marvellous. The instrument was shown at a meeting of one of our Philosophical Societies, and I can remember that many members were disappointed—because this process was not colour photography as they understood it. They wanted something one could take home and put in an ordinary frame or album. The results, however, were none the less pleasing, and when one looked at the pictures in the little instrument one could easily see that no artist had ever painted such a variety and delicacy of tint. Of course it is a serious drawback that the pictures can only be seen when viewed in this specially arranged apparatus, or upon a lantern screen.

Referring again to the simple vase of flowers, used as an illustration in describing Ives' process, it will be noted that we only dealt with four colours—red, green, yellow, and blue. It will be remembered, however, that all the variety of colours existing can be made up by blending together the three primary colours—red, green, and violet. Therefore every colour when filtered through these three colour screens will leave a record either on one, on two, or on the three negatives. A white object, being all three primary colours blended together, will affect all three negatives in certain definite proportions. When the three primary colours are again blended together by means of these records they will reproduce a white object. If one is not familiar with the results obtained by blending different colour rays together, all one need remember for our present purpose is that on the first plate is recorded all the red rays, on the second plate the green rays, and on the third plate all the violet rays. It makes no difference whether these rays are visible as red, green, or violet, or whether they are mixed up together, forming other compound colours.

It must be clearly understood that all the blending of colours with which we have been dealing has been a blending together of coloured rays of light. It is usual to say that the mixing of coloured pigments gives quite different results from the mixing of coloured lights. The ordinary reader feels as though he had been landed in a fog. The statement requires some elucidation. One must remember that in mixing so-called colour pigments we are merely manipulating the colour rays present in the light falling upon the pigments. I shall only touch upon this subject very briefly at present, as a fuller explanation will be of more direct interest when we are considering the making of three-colour book illustrations.

I feel sure that some reader has thought in reading the preceding part of this chapter that it seemed strange to speak of green as one of the three primary colours. As very youthful artists we may remember mixing yellow and blue paints together to produce green. We therefore have the impression that green is a compound colour, and not one of the three primary colours. At present we shall be contented with general statements, leaving the detail to be filled in later, as already suggested. Looking at our mixture of the two paints, we may imagine the combined efforts of the blue and the yellow pigments to have absorbed all the red and violet rays, leaving only the green rays to be reflected; we therefore see the mixture to be green.

The once youthful artist says that surely a blue and a yellow glass, if placed together in a lantern, will also produce green upon the lantern sheet. Certainly they will; the result will be just the same as got by mixing the blue and yellow pigments.[1] But in making our coloured

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[1] We have in the light of the lantern red, green, and violet rays, and these endeavour to pass out of the lantern. But the blue glass obstructs, or cuts off, all the red rays, and allows only the green and

pictures upon the lantern sheet we did not place two coloured glass screens together in one lantern; we had a separate light for each colour. If we blend the blue and yellow lights together by that method, throwing the two separate colours directly on to the lantern sheet, we find that we have produced a practically white sheet. There is no green now. How is this, and wherein lies the difference?

The first case seems simple enough. We filtered a white light through both a blue and a yellow screen, placed one behind the other. The white light consisted of red, green, and violet rays, but the two screens managed to cut off all the red and all the violet rays, leaving only the green rays to pass through and reach the lantern sheet. The second case is different, but is also quite simple. We have a separate white light for each colour screen. We first of all throw one light, say, through the blue screen. It allows both green and violet rays to pass through it, cutting off only the red rays; we therefore see the sheet to be this compound colour called blue, which is due to the green and violet sensations being simultaneously stimulated. Now when we throw another separate light through the yellow colour filter, we allow both red and green rays to reach the sheet, only the violet rays being cut off. But we already have the violet sensation stimulated along with the green sensation, and if we now add

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violet rays to pass. These are encountered by the yellow glass screen, which obstructs all the violet rays, leaving only the green to pass out of the lantern. That is to say, the light in passing through the first screen is robbed of all its red rays, and then it is robbed of all its violet rays by the second screen, so that green rays only issue from the lantern.

red, and more green, we have all three sensations simultaneously excited, so that we have the resulting sensation of white light.

Must we bother with all this detail concerning colour in a chapter dealing with colour photography? I see no way of forming a clear conception of the subject unless we are willing to take this trouble. The subject is really not a complex one, if we let the little five-year-old fellow remind us occasionally that all colour is summed up in red, green, and violet.

Before closing this chapter it may be of interest to give a short summary of what Ives' process of colour photography does. First of all a separate record is taken of each of the three different colour rays sent back from the objects we are photographing; not only where these primary colours are recognisable, but wherever they exist in combination with one another, forming compound colours. These three different records are then used to reconstruct the coloured picture. Each record controls the amount of its own colour falling upon the different parts of the lantern sheet. Ives only throws red, green, and violet lights upon the lantern sheet, but these three colours when recombined by the records which they themselves made produce upon the lantern sheet all the variety and delicacy of the colours in the original objects. Ives therefore adopts a different method from that of the artist when painting a picture. The artist mixes his pigments until they collectively cut off all the rays which he does not wish to be reflected from the canvas, and reflects only those rays, or combinations of rays, which he desires to stimulate our sensory organs. The artist starts with one bundle of red, green, and violet rays (white light), so that all his manipulations must necessarily be cases of subtraction. Ives, however, has three separate colour pencils, red, green, and violet lights, which he may add together as he desires, and therein really lies the difference between blending coloured rays of light and mixing coloured pigments.

Ives' process is excellent, but it must be admitted that the results have taken us no nearer the public's ideal of colour photography. It may be mentioned, in passing, that Ives has constructed a camera for taking all three negatives at one time. He uses only one lens, but separates the different rays by means of colour screens placed inside the camera. These three records may be taken upon one plate, but they still remain as three distinct and separate pictures on different parts of the plate. It is only a matter of convenience having the three negatives on one sheet of glass.

Probably some readers, accustomed to photographic work as amateurs, may have wondered how the red rays have been able to make any record at all upon the photographic plate. The photographer uses a red light in his dark room and does not hesitate to examine his sensitised plates in this light, knowing that the red rays will have no effect upon the sensitive film. How then are the red rays to make a record in the camera? It is clear that we cannot use an ordinary photographic plate. Plates are specially prepared for colour photography. The chemical films on these plates are sensitive to red rays as well as to green and violet.

Any further detail concerning this interesting and beautiful process of Ives would be beyond our present purpose.

Much of the detail concerning the nature of colour, etc., contained in this chapter will be of service to us in the proper understanding of the other processes of colour photography which are described in the two following chapters.

CHAPTER VI

MORE ABOUT COLOUR PHOTOGRAPHY

A threefold record on one negative—Joly's process—How the colouring is reproduced—An analogy from fancy weaving—Negative and positive—Another ingenious method—Why some processes do not use the primary colours—How the natural colours are reproduced—The colour filters—A simple illustration—A complete lantern slide—Dissecting a Sanger Shepherd slide.

IN Ives' process, described in the preceding chapter, it was necessary to take three separate negatives—one being a record of the red rays, another of the green rays, and the third of the violet rays. Could we not take all three records on one plate as one complete picture, instead of having three separate pictures, each containing only a part of the whole? If we have followed the particulars about colour in the preceding chapter, it will be quite clear to us that it would be useless to try and take a photograph through all three colour screens or filters at one time. Suppose we do place the three screens in the camera, one behind the other. The light entering the camera first of all meets the red screen, which cuts off all the green and the violet rays, and allows the red rays alone to pass in. These red rays are immediately obstructed by the green coloured screen, leaving no light to pass in any further. If we try any two of the coloured screens we shall find that they alone are sufficient to obstruct all the light. No light, no photograph.

We are quite convinced that there is no use of attempting to take one complete record of all three colours through the combined colour screens; we have seen that the result would be a blank. Professor Joly, of Dublin, however, has shown us that it is possible to get the whole three records in one negative by a single process. The method adopted is both interesting and ingenious. Instead of three separate colour screens—red, green, and violet—we take one clear glass screen and then paint thin lines of these colours upon it. We first of all paint or rule a very fine line of red across the glass plate. Right alongside of this we paint a green line, and next to that a violet line, each line touching its neighbour. Then again we paint another red line, and so on—red, green, violet, red, green, violet—until we have the whole plate covered with coloured lines.

This striped screen will not cut off all the light now. Each line of red will allow red rays to pass through that line, so that a photograph of a red vase taken through this screen would show the image of the vase in separate parallel lines. The lines, however, are very close together, and if the picture is looked at from a little distance the image has the effect of being solid. The green objects will be recorded in similar fashion through the green lines, and the objects reflecting violet rays are recorded through the violet lines. Although the red, green, and violet rays have had to pass through different lines, or slits, all the rays have found an open door, so that the resulting negative contains a complete record of the objects

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A Bad Fall

Needless to say the fall was not a matter of arrangement. The photograph was taken in one seven-hundredth part of a second by means of a Thornton-Pickard Focal-plane shutter.

photographed. There is, of course, no colour on the photographic plate; we have merely sorted out the rays and taken a black and white record of each colour forming the picture.

In Joly's process we have the three separate colour records lying in consecutive parallel lines or stripes, whereas in Ives' process the three records are on separate plates. The taking of the Joly records is naturally a much simpler process, but how are we going to reproduce the coloured picture? We must, of course, throw red rays through that part of the record made by the red rays, and so on. This is really very simply done. We place the screen with the coloured lines immediately behind the threefold record, taking care that the red lines are exactly opposite the lines representing the red record, and similarly with the other coloured lines. We thereby recombine the rays and reproduce upon the lantern sheet all the beauty of the original delicate colouring. If one is close to the lantern sheet, the lines are noticeable; the picture appears in stripes. If one is at a little distance, the individual lines are not seen, so that the picture appears solid, and the delicacy of the natural colours is marvellous.

It occurs to me that we have a good analogy of Joly's process in the art of fancy weaving. The weaver desires to produce upon a cloth a conventional floral effect in which there is to be a yellow flower with a red edge surrounding it and a patch of green at its centre. What he really does is to throw first a yellow thread across his web with one shuttle, bringing the yellow to the surface of his cloth wherever he wishes it to be seen. He then throws a second shuttle filled with red yarn, and after that a green shuttle. The weaver's method is very similar to Joly's process. The weaver has three successive lines of coloured yarn repeating all the way across his piece; Joly has three coloured lines all the way across his picture. The picture in each case is built up by these lines showing at some places and not at others. The lines follow each other so closely that they are not distinguishable as separate lines when viewed from a little distance.

I think we may carry our weaving analogy a little further. If a weaver desires to make a cloth, using only two colours for producing the figure, he often brings in a third colour effect by mixing these two colours in a solid mass. He may make a yellow object with a blue edge, and then by mixing these two colours together at one part he produces the impression of green. Most of us have seen fancy looms at work at our international exhibitions or elsewhere, and we know that the design in the cloth is produced by a machine on the top of the loom. We need not trouble about the details of this *Jacquard* machine. It will be sufficient, for our present purpose, to know that it contains several hundreds of wire needles, which are controlled by holes punched in cards, and that these needles in turn control the threads of the warp which are stretched out in the loom below. Each card represents one throw of a shuttle, the warp being opened to let the shuttle pass through, so as to bring the yarn in the shuttle to the surface wherever it is wanted. We therefore see that the holes in one card represent the yellow yarn which is to show, while the holes in the next card represent the blue yarn which is to come to the surface. But what about the green patch of colour? It must, of course, be represented by holes in both cards, as it is a combination of both these colours. In a similar sense, we must remember that when we record the red rays of light in colour photography we not only record rays from the red objects, but also from all objects whose colour has red rays contained in it.

It will be quite clear to all that when the threefold record is taken in the camera, the developed negative will only show black lines of varying density wherever the different rays have affected the plate. In order to reproduce the picture we wish the reverse of this, so that we may have, as it were, clear slits to correspond with the parts on which light fell. We therefore make a positive from this negative in the usual way, and then we can make light shine through those parts of the positive record which were affected by light on the original negative.

The subject of negative and positive is so simple to all those who are accustomed to photographic processes that it would seem quite unnecessary to refer to it again. However, as I have sometimes found that the *why and wherefore* of this subject is not clearly understood, it is worth while referring to it once more. We may picturesquely think of the light entering the camera and attacking the chemicals upon the sensitive plate, and wherever it strikes, altering the chemical condition of that part of the film. On looking at the exposed plate in the "dark-room" we see no effect upon the chemical surface. When we place the plate in a developing bath the liquid soon darkens the chemicals which have been affected by light, leaving the affected parts as black patches of varying densities. Our negative is therefore opaque wherever it represents a white object, and clear glass wherever it corresponds with a dark object or shadow (see illustration opposite p. 50). This is just the reverse of what we wish for our magic lantern. We wish to let light shine through the image of a white object and obstruct the light by the image of a dark object. The record of our white object cannot therefore be opaque, but must be clear glass. We have no difficulty in obtaining a reverse of our negative. We place the developed negative with its picture in contact with a second sensitive plate, and allow light to pass through and attack the chemical film on the second plate. As the image of a white object is solid film on the first negative, that will prevent any light reaching the second plate at that part, so that the film representing this white object on the second plate will be left clear glass through which we can now throw the light of the lantern and form a bright image of the white object upon the lantern sheet.

It is clear that every lantern slide of Joly's process must have a ruled screen of colours bound up with it. Can we not dispense with this line effect and make a coloured lantern slide complete in itself? We shall see what has been accomplished.

We return to the original Ives' method of taking three separate negatives, but we wish to reproduce the picture by one lantern slide requiring only one light. We have already seen that there is no good in placing red, green, and violet screens together in one slide. It will be remembered that any two of these screens placed together will cut off all the light from the lantern. Each screen cuts off two of the three primary colours, so that any two of the screens will annihilate all three primaries. We are attempting to work on quite a different plan from that adopted by Ives in reproducing his pictures. He had three separate lights, giving red, green, and violet rays respectively. These he could add together at will by his three separate transparencies. We are now starting, however, with all our three colours blended together in one light, so we must subtract the rays we do not wish for from each part of the picture. If we must always subtract two of the colours at one time we are helpless; we want at some parts of the picture to subtract only one primary and allow the other two to reach the lantern sheet blended together. What we really want, then, is to be able to subtract each of the primary colours one at a time. Colour screens, or *filters*, have been made for this purpose by Lumière (France), Sanger Shepherd (England), and others, who have devised a very beautiful process of making complete colour lantern slides.

First of all we wish for a screen, or colour filter, to cut off only the red rays. In other words, we wish for a screen to permit both green and violet rays to pass. We must keep in mind that we are dealing with the blending together of coloured lights, and not with the mixing of colour pigments. Although it will be necessary to prepare dyes in order to colour the screens, or filters, we shall not concern ourselves with the dye stuffs. To simplify matters, we shall only deal with the mixing or blending of the coloured lights.

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In order to make matters quite clear, it would be well to make a few experiments with a triple lantern such as is used by Ives in his process. We have three separate lights exactly overlapping one another upon the lantern sheet. Perhaps our simplest plan will be to place all three colour slides in the lanterns. We have a red, a green, and a violet light, all overlapping one another, and the result is that the lantern sheet appears white. It does seem strange that all three colours falling upon the sheet produce white. Some people think of white as being devoid of colour; it is clear that white is our whole stock of colours blended together. When all our three colour sensations are simultaneously stimulated, then we see white.

Now we wanted to make a colour screen which would cut off only red rays. What colour must we use for this purpose? It is very easy to find this out, for we have red, green, and violet rays all falling upon the lantern sheet at present, producing white light. If we close the lens from which the red rays are being thrown, we shall then have only green and violet rays reaching the sheet. Instead of being white, the lantern sheet now appears a greenish-blue colour. Therefore, if we make a dye to match that colour, we shall be able to make a screen to cut off the red rays only. If we have a thin sheet of celluloid with a coating or film of gelatine upon it, we may dye the gelatine on the screen by dipping it into the bath of greenish-blue dye.

To those who can picture the appearance of the solar spectrum with ease, there should be no difficulty in remembering that the greenish-blue slide, being a combination of green and violet rays, will cut off the red rays only. In order, however, to make matters perfectly clear, we shall not trouble further with the appearance of our colour filters, but merely remember that No. 1 screen cuts off all the red rays.

Those readers who have taken the trouble to make a book-mark with the colours of the solar spectrum upon it, as suggested in the preceding chapter, will find it of interest to note below the colour red, *minus red = greenish blue.*

Our next colour filter is to cut off only green rays. We put all three colours on the lantern sheet again, and once more we see the sheet to be white. This time we cut off the light from the lantern throwing the green rays, leaving only red and violet to fall upon the sheet. The sheet now appears a crimson pink colour, being a combination of red and violet rays. We therefore dye our second gelatine film to match this colour. Below the green colour on our book-mark we may note, *minus green = crimson-pink*, but we shall only speak of this crimson-pink filter as No. 2 screen, being content to know that it cuts off green rays only.

Our third filter is to cut off the violet rays, so we had better turn on all the colour lanterns once more and produce a white sheet. This time we cut off the violet lantern, and we leave only the red and green lanterns to light the sheet. The result is a yellow lantern sheet. This is quite what we should expect, for if we look at our book-mark we find that yellow lies between red and green, being an overlapping or blending together of these two primaries. Hence the red and green lanterns blending their lights together on the lantern sheet produce yellow. We must therefore dye our third colour filter to match this yellow. We shall simply call this No. 3 screen, remembering that it cuts off the violet rays. To complete the book-mark, however, it will be of interest to add under the violet colour, *minus violet = yellow.*

Now we have three screens; No. 1 cuts off all the red rays, No. 2 cuts off all the green rays, and No. 3 cuts off all the violet rays. If we place all three screens together, one behind the other, in one lantern, we shall cut off red, green, and violet rays, and no light at all will pass out of the lantern. Suppose, however, that we scrape away a little of the dyed gelatine from No. 1 screen, which is cutting off the red rays, we shall then allow red rays to pass through at this point. The other two screens cut off all the light except the red, so the red light can now get out of the lantern through the space we have scraped clear.

Let us deal with red alone first. We can now see how it will be possible to reproduce upon the lantern sheet an image of the red vase. We take the first, or red, negative produced by Ives' process. This negative has an opaque image of the vase upon it, so we shall print a positive of this on to a sensitised film of gelatine held upon a thin sheet of celluloid. When we develop this we have a transparent, or clear, image of the vase, and an opaque ground on the rest of the plate. In other words, we have no gelatine left where the image of the vase is. If we now dye this gelatine transparency to match No. 1 screen, and use it in place of the colour screen, it will cut off red light except at that part forming an image of the vase. It is just as though we had neatly scraped away an image of the red vase upon our original No. 1 screen, and then placing the other two screens behind this one in a lantern, we allow only the red light to pass out through the clear image of the vase on No. 1 screen.

I have spoken of developing the gelatine transparency after printing from the negative, but the process adopted hardly warrants the title of developing. After the sensitised or bichromated gelatine surface of the celluloid plate has been exposed to light, under the original negative, it is only necessary to wash the exposed plate in warm water, whereupon the parts which have not been affected by light will be washed away. In this case the opaque image of the vase upon the original negative protected the gelatine, while the remainder of the gelatine was affected by light. Hence our resulting transparency or positive would show no gelatine for the image of the vase, but a complete ground of gelatine over the rest of the plate.

Let us examine the lantern sheet more closely, and we find not only a red vase upon an otherwise dark screen, but we also see a red image of the original yellow flowers. Suppose we now scrape away a patch of the gelatine on No. 2 screen, which is obstructing the green rays. We shall at once see a patch of green light upon the corresponding part of the lantern sheet. It follows that if we dye a transparency made from Ives' second or green negative, and substitute it for No. 2 colour screen, we shall cut off all the green rays except at the clear image of the leaves. It will be remembered that a clear image of the original yellow flowers will also appear upon this transparency; the green rays will not be subtracted from the flowers, nor were the red rays, therefore they will appear yellow.

Following up the simple plan of scraping away a patch of gelatine film from the colour screens, we find that in doing so to No. 3 screen we permit violet light to pass out to the lantern sheet from this cleared patch. We therefore make a third transparency from Ives' third or violet negative, and we dye it to match our No. 3 dyed screen, which cuts off all the violet rays. It will be remembered that this third transparency will throw an image of the blue figuring upon the vase. This image will be thrown in violet light, but as the green transparency will also have thrown an image in green of the same figuring, the image will now be turned to blue. We now have a complete picture upon the lantern screen: a red vase with blue figuring upon it, some green leaves and yellow flowers.

The picture which we have just built up upon the lantern sheet is the same as that built up by Ives' process. Wherein then lies the advantage? It is self-evident. In Ives' process we required three separate lanterns, with three separate lantern slides, all to be carefully adjusted to exactly overlap upon the screen. In Lumière's and Sanger Shepherd's processes we have only one lantern and one lantern slide, which requires no special treatment; the slide may be exhibited by any amateur in the ordinary way. The three dyed transparencies are mounted together between two ordinary plain cover glasses. It is more convenient to have one of the dyed films upon glass, and then place above this No. 2 celluloid with its dyed film, and over that again No. 3 celluloid. These are now bound together by placing a plain cover glass over them. The two celluloid sheets are very thin, so that the complete lantern slide is practically no thicker than an ordinary slide. Of course, it is necessary when mounting to see that the three pictures exactly overlap, but this is done once for all in making up the lantern slide.

I have purposely taken a very simple illustration for our lantern slide, but we have seen how the three primary colours and two compound colours (yellow and blue) are recorded and reproduced. In the same manner the most intricate colourings may be analysed and reblended together.

I have in my hand a lantern slide produced by the Sanger Shepherd process. It is a photograph of a large basket of different fruits. No artist could produce such a natural bloom upon those grapes, nor the infinite variety and delicacy of colour in the photograph. I take off the plain cover glass of the lantern slide and below this I find first of all a yellow film, upon which there appears a faint transparent image of some of the fruit and basket. This is the No. 3 screen which will cut off the violet rays excepting where the screen is left transparent. The most opaque object I can pick out upon this plate is a large apple, a considerable part of which is dyed yellow. This means that practically no violet rays will be allowed to pass through this image of the apple. Removing this yellow transparency, we next come to the crimson-pink film, which is also on a thin sheet of celluloid. Here we also find a good deal of the picture as a transparency on the crimson-pink ground. Looking at the same apple as before, we find its image upon this plate is also fairly opaque and is dyed deep crimson-pink. This means that practically all the green rays will be cut off from this particular apple.

If we now remove the crimson-pink transparency we find a greenish-blue transparency fixed to the under glass cover. We see a good deal of the whole picture again as a transparency upon this. Picking out the image of the particular apple which we have already examined on the other transparencies, we find that it is almost quite transparent on this last plate. It has almost none of the greenish-blue dye which cuts off red rays. Now placing the three coloured transparencies together again, we have the first-mentioned one obstructing the violet rays from this particular apple, while the second transparency obstructs the green rays from the same object, therefore leaving only the red rays to pass unobstructed through the clear image of the apple on the third transparency.

CHAPTER VII

COLOUR PHOTOGRAPHY WITHOUT COLOURED SCREENS

A brief summary—Is colour photography a delusion?—A process without coloured screens—Lippmann's method—Its principle—How the colours are produced—Photographing the colours—What happens on the photographic plate—Another colourless process of reproduction—What is a diffraction grating?—A demonstration—Wood's process—Early observations—Conclusion.

LET us now make a brief summary of the three different processes of colour photography which we have considered up to this point. Ives made a separate negative of each primary colour—red, green, and violet—thus recording the whole light reflected by the objects he photographed. He then made transparencies of these three records, and by using three separate coloured lights he could reproduce his picture, controlling each colour by the record it had made itself.

Coming next to Professor Joly's process, we found that he took the three primary colour records in consecutive lines on one negative. By means of a viewing screen he again threw the three primary colours through these line records, and thus reproduced the original coloured picture.

In the third process we find Sanger Shepherd reverting to the three separate negatives of Ives. He then dyes three transparencies of these records. He does not use the primary colours for dyes, but obtains three colours, each of which will only cut off one set of rays and allow the other two primaries to pass through, from the white light in the lantern. This, as we have seen, gives us the advantage of being able to mount all three coloured transparencies together in one lantern slide.

The reader may consider it a simple delusion to speak of any of these processes as being photography in natural colours, no matter how beautiful the results may be. Our methods have been artificial; we have used coloured screens and coloured dyes. We have certainly done so, but only in order to control the coloured rays composing the white light. Perhaps this will be more clearly understood if we consider what we really did when we reproduced in imagination the simple photograph of the red vase with its flowers. How did we reproduce the red vase in Sanger Shepherd's process? We started with the ordinary white light of the lantern, which in passing through the yellow filter was robbed of its violet rays, and then passing on through the crimson-pink filter it was further robbed of its green rays, leaving only the red rays to pass through the transparent image of the vase on the third filter. We did not dye the vase red; we manipulated the colour rays in white light, subtracting all but the red.

I can see some matter-of-fact reader shaking his head. He says it is all very well to talk of colour in that way, but there is no getting away from the fact that we have used coloured screens. I ask him if he will be satisfied if I can show him a photograph in natural colours, which

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TEN PHOTOGRAPHS OF FIVE CRIMINALS

The photographs in the upper row were all taken some time before those in the lower row. Each pair of photographs is of one criminal. It is difficult to realize that the men in the lower row are the same as those immediately above. (See chap. xi.)

was taken and reproduced without the aid of any coloured screens whatever. He is interested at once.

When the expectant inquirer is shown one of Professor Lippmann's beautiful photographs on glass, in which all the delicacy of natural colours is seen, he at once concludes that there are coloured screens in this slide also. We are not showing him this picture upon a lantern screen. We cannot do so; it must have a reflecting back of mercury. If we take the photograph away from the mercury back and let him look through the glass photograph, he is convinced that there is no colouring on the plate. There is no colouring upon the mercury, which merely acts as a good reflecting surface. From whence, then, comes all that beautiful wealth of colour when the transparent photograph is placed against the mercury background? From the place that all colour comes from—out of ordinary white light. This seems very mysterious; but let us watch some child blowing soap-bubbles. How do the colours arise? Why do they keep changing?

When light falls upon the soap-bubble it is reflected back, not only by the outside surface of the bubble, but by the inner surface of the same wall or film. We have nothing to do at present with the other side or wall of the soap-bubble; it is only the one very thin film which concerns us.

When the film or coating of the soap-bubble is of a certain thickness it transmits all the red and green rays, but reflects back the violet rays. This phenomenon is due to the reflection from the inner side of the thin film interfering with the reflection from the outer surface.

We merely observe that as the soap-bubble coating varies in thickness, the colours which it reflects also vary. Therefore if we can make a very thin photographic film on a sheet of glass, and if we can arrange that this film can be of varied thicknesses, we shall have different colours reflected thereby. Light will not only be reflected by the surface of the film, but also by the mercury backing, and the thickness of the film between its outer surface and the mercury reflector will determine the colour which will be reflected.

What I have been briefly describing is really what Professor Lippmann has successfully accomplished in his process of colour photography. He arranges a thin transparent film which is sensitive to light; this he places against a mercury background, so that when the light enters the camera it not only attacks the surface of the film, but is reflected back through the film by the bright mercury background, which is in immediate contact with the back of the film. The sensitive film is therefore being attacked both by waves of light falling directly upon it and by waves of light reflected back by the mercury surface. There is an interference between these two sets of waves of the all-pervading ether. At some parts the one set of waves will go to assist the other set, and at such places the action upon the chemicals in the film will be considerable, so that a comparatively thick deposit is made. The deposit will really be in very thin layers separated by other thin layers of clear film, according, as it were, to the rise and fall of the ether wave (light). At other places one wave may go to neutralise another, and so on. The actual working of light in the taking of Lippmann's photographs is a much more complex phenomenon than such a simple interference of waves as I have just described. Different colours are due to different sizes of waves in the ether, so we have not only to deal with two sets of simple waves. However, what we have to picture, at present, is merely a film so formed with varying layers, corresponding to the wave lengths of different colours. The existence of these layers in the film is not merely theoretical, they can actually be seen in the microscope, and photographs of them have been taken through the microscope. A colour wave does not form only one layer in the film, but a series of layers, the distance separating these layers corresponding with the length of the wave producing them.

We now come to consider the reproduction of the coloured picture. Although it may seem, at first, incredible, it is a fact that when the film, thus formed, is developed and dried it will again reflect back all the different wave lengths (colours), which produced the different layers. It is, of course, not a case of simple reflection. The photograph must have its mercury background to set up a second reflection which will interfere with the reflection from the front surface of the film. The soap-bubble is a complete analogy; indeed the phenomenon in both cases is identical. Some layers will reflect to the eye only red waves, other parts green waves or perhaps violet waves, but other parts will have layers which reflect back both red and green waves together, producing the sensation of yellow. In this way every variety of colour which affected the sensitive film is reproduced.

Before leaving the Lippmann process, which has only been very briefly described, it may be well to remark that the photographs taken by this process are usually viewed in a dark box with an eyepiece. A strong light is reflected into the box to fall at a certain angle upon the glass photograph. While this is an improvement it is not an absolute necessity.

There is another process in colour photography which requires no colour screens in reproducing its pictures. This process was discovered, or I might rather say invented, by Professor Wood, of Wisconsin (U.S.A.). It is dependent upon the diffraction of light by means of glass plates with lines ruled very close together, two or three thousand lines to the inch. This process would not be easily understood without going into it at considerable length, and would require a series of diagrams. I therefore pass it over, only remarking that Professor Wood uses colour screens in obtaining his photographs, but he reproduces them by means of these finely ruled screens, known as *diffraction gratings*, without the aid of any colour screens. Lippmann's process was entirely free of colour screens both in the taking and in the reproducing.

These two processes are really only of scientific interest. One cannot hope to practise such methods with pleasurable ease. What the man in the street really wants is a direct method of colour photography. He wishes to take a simple photograph, develop it, and find all the colours already there.

Many people have maintained that this will be for ever impossible. In these days of discovery it is not wise to be dogmatic in one's prophecies.

WITHOUT COLOURED SCREENS

Has nothing been done to try and get the different colours to fix themselves directly on to a sensitised plate or paper? In connection with the early experiments in photography, both Daguerre and Fox Talbot stated that sometimes they had found the red objects in a scene to impress themselves upon the photographic plates with a distinctly red tinge. This would, no doubt, be put down to some chance chemical coincidence. Several well-known men of science, however, succeeded in getting light, when passed through a glass prism, to make a coloured record upon a sensitised surface. The resulting spectrum band was by no means perfect, but some of the colours were fairly good. These colour effects, however, were difficult to obtain, and they did not live long; even exposure to air seemed as destructive as further exposure to light.

Such experiments were known to scientists more than a century ago—quite a generation before photography was invented. One might therefore be inclined to say that direct colour photography cannot lie along these lines. Within recent years, however, particular attention has been given to the possibilities of direct colour photography, and some interesting progress has been made.

Some time ago a *bleaching-out* process was introduced, and has recently been improved by Dr. J. H. Smith, of Zürich. Through the kindness of a friend I have been able to test a piece of this bleaching-out paper. The sensitised paper looks as though it had already been exposed to light; it is almost black. I first of all placed four strips of coloured celluloid alongside of each other—a green, a yellow, a blue, and a red. When the paper was exposed to light through these colour screens, each colour impressed itself with fair approximation upon the paper. That is to say, where green light fell upon the paper it turned green, yellow light recorded yellow, and so on. The piece of paper with which this experiment was made took an exposure of four hours in good daylight.

The next experiment was to try printing a coloured picture. Taking a coloured lantern slide and removing the plain cover glass, I made a contact print through the lantern slide. The coloured print thus obtained was a very fair representation of the original. This again required an exposure of four hours in good daylight. Dr. Smith has every confidence in making the surface more sensitive, so that a much shorter exposure would be sufficient.

It will be obvious that a glass plate or a film prepared in this way and placed in the ordinary camera should record the coloured picture falling upon it. A friend asked me if I could procure him a piece of the paper, in order to try it in the camera. I pointed out that it was not sensitive enough for that purpose. What he proposed doing, however, was to leave the paper exposed in the camera in front of a stained-glass window, and the exposure might be for a week, if necessary. I do not believe that any impression could be got in this way. The light would be too weak to affect the chemicals, just as was the case in the early experiments of Wedgwood and Davy with the camera obscura. The chemicals require a certain intensity of light to affect them, the intensity depending upon the chemical combination. To take a simple analogy, we may imagine a glass plate upon which certain small objects have been fixed. We arrange matters so that a strong blast of air projected upon the surface blows these objects away from their anchorage. It is quite obvious that we might let a gentle stream of air play incessantly upon the same plate without having any effect upon the objects.

This bleaching-out process of colour photography only awaits some means of making the surfaces more sensitive, and in adjusting the chemicals so that the colours produced will be as near to nature as it is possible to have them.

I cannot do better than close this subject by again repeating the words used by Arago before the French Chamber of Peers in 1839:—

"The image in its natural and varied colours may remain long—perhaps for ever—a thing hidden from human sagacity. But let us not rashly circumscribe knowledge within impassable bournes. The successful efforts of M. Daguerre have disclosed a new order of possibilities."

CHAPTER VIII

THE MAKING OF BOOK ILLUSTRATIONS

The first beginnings—Woodcuts and engravings—The meaning of etching—Niépce's early experiments—A failure followed by success—Heliography—A surprise reproduction of some diagrams—A visit to the block-maker's—How the blocks are made for the printer—A demonstration of Scott Archer's wet collodion process—Zincotype process for line drawings.

IN order to understand clearly how our present beautiful results in book illustration have been attained, it will be of interest to trace the subject, briefly, from its earliest beginnings.

We are not surprised to find that we have to begin in China. Indeed, one sometimes feels as though the Chinese had discovered everything before the world began. The Chinese observed that a block of wood, if smeared over with a particular kind of ink, would leave a clear impression of itself upon a piece of paper. The idea was soon suggested that if they cut away part of the surface of the block, and left only the lines of one of their language signs, an impression of this sign could be made upon paper. The successful printing of these language signs led the Chinese to make wooden blocks with figures and images upon their surface.

It is not known exactly when this wood-block engraving was introduced into Europe, but some museums possess prints dating back at least four or five centuries.

These early woodcuts were merely outlines and spaces; there was no attempt at shading. The art of wood-engraving attained to great perfection in modern times, but photographic processes have now stepped far in front, and completely revolutionised book illustration.

In order that we may properly appreciate the part now played by photography, it will be well to note briefly how hand engravings are made on metal plates. The art of engraving upon metal is far older than the art of printing. Gold and silver ornaments had for long been embellished by engraving designs upon their surface. The goldsmiths of Florence increased the decorative effect by filling the engraved lines with a black enamel after the design had been completed. While at work they had difficulty in seeing the part of the design which they had already cut. They therefore adopted a plan of inking over the vase or ornament occasionally, and then cleaning the surface of ink, they pressed a damp paper against the vase, and found that they could get a clear impression upon the paper of the lines they had already cut on the metal. It was a long time before any one suggested this kind of engraving as a means of printing pictures.

It will be observed that engraving upon metal is exactly the converse of wood-engraving. In the latter the engraver cuts away all the wood except where he desires lines to print from, whereas the metal engraver cuts out the lines themselves, leaving them as depressions in the plate. In the woodcut, therefore, the design stands up in relief, and by passing an inked roller across its surface it will receive ink, and that in turn is transferred to the paper. All such blocks, on which the lines stand up like type, are called *relief blocks.* Those blocks or plates which have the lines sunken below the flat surface are called *intaglio*, and it is obvious that such plates cannot be printed from in the same manner as in the relief process. If we were to pass an inked roller over an intaglio plate we should ink the plain surface and leave the lines of the picture without ink. It is therefore necessary to dab on the ink so that it may fill up the depressed lines, and then clean the plain surface; a process which must be done by hand. If a suitable paper be then pressed against the engraved plate, by means of a hand-press, the ink will be transferred from the lines to the surface of the paper. We have photographic processes on both these principles, but it will be of assistance to us to note briefly the method of *etching* metal plates.

The word *etching* is often used erroneously in connection with ordinary pen-drawing upon paper. The process of etching metal plates consists, first of all, in covering the surface of the plates with some composition which will resist the action of acids. The desired design or picture is made on paper, and transferred by pressure to the surface of the composition. The etcher then goes over the lines of the transferred drawing with a special needle, cutting away the resisting composition wherever he finds a line. When this has been done he pours some etching fluid or acid over the plate, and the acid soon eats its way into the metal wherever the resisting surface has been removed by the etcher. The result is a metal plate with the picture sunken into it. This is

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THREE CRIMINALS AND THEIR THUMB-PRINTS

Any one of these three criminals' photographs might be mistaken for the other. Their thumb-prints, as shown beneath each portrait, could not be so mistaken. (See chap. xi.)

therefore an intaglio process, and the plate must be printed from in the same manner as a hand-engraved plate.

It will be obvious that the etched plates required to be prepared by some one with artistic talent, or at least some one well able to draw. It was our old friend Nicéphore Niépce who first suggested that the etched plate might be automatically produced by the action of light. Niépce was very interested in the mechanical printing of pictures by means of lithographic machines, which had not been long in use at this time (1814). Niépce set about trying to make improvements in this much-praised invention of Senefelder. One suggestion made by Niépce was that metal plates should be used in place of blocks of special stone. It was while experimenting in this way that the idea occurred to him of transferring the lines of the picture to the metal plate by means of light itself. Experiments with the salts of silver failed to serve any useful purpose. The impressions got could not be fixed. It was then that Niépce made experiments with the bitumen of Judea, of which we read in the first chapter.

The bitumen of Judea did not turn black, like the silver salts, on exposure to light. What happened to the bitumen was something quite different. If it was dissolved in certain oils and then spread over a metal plate and allowed to dry, it became sensitive to light. The action of the light was such that it altered the chemical condition of the bitumen. After exposure to light, it was found to be no longer soluble in the oils which previously dissolved it. Here was a way out of Niépce's difficulty. He now exposed the plate with its bitumen surface under the transparent drawing. Wherever the light got through to the bitumen those parts became insoluble, but wherever the lines of the drawing protected the bitumen it still remained soluble. When the exposed plate was then placed in the oil bath, the soluble parts, corresponding to the lines of the picture, were dissolved away, leaving the plate exposed at such places. The plate could now be etched by acid in the same manner as a plate prepared by the etcher's needle. No artist but Light was required to prepare the etched plate. Niépce called this process *heliography* (sun-drawing), and undoubtedly it forms the starting-point for all subsequent processes.

It would only weary the reader to follow out all the processes leading up to our present means of reproducing drawings or photographs for book illustrations. What the reader really wishes to know is, how we are able to take a photograph and print it by purely mechanical means, like ordinary type. In other words, how can photography make the blocks for producing such illustrations as we have in this present volume.

Many years ago, in writing some articles for one of our scientific journals, I drew out a number of diagrams, upon which I scribbled several words opposite different parts, thinking that the block-maker or the printer would set these in type. I was very much surprised, upon receiving the proof-sheets, to find that these ugly scribbles of mine appeared in the printed diagrams, exactly as I had hurriedly put them upon the original drawings. It was quite apparent that the block-maker had simply photographed the diagrams and put them, by some means, directly on to his blocks. Needless to say that in future diagrams I took care to carefully print in any words required. How then did the block-maker reproduce the diagrams on his blocks?

I think it will be of interest if, in imagination, we pay a visit to the block-maker's. We are fortunate in arriving just as the block-maker is preparing to photograph a pen-and-ink drawing for reproduction in one of our newspapers. He has placed the drawing upon an upright board, but his camera seems to be pointing in quite a wrong direction; the drawing is at the side of the camera, and not facing it. When we go round to the front of the camera, however, we find that the lens is turned round at right angles, so that it is really facing the drawing. How then will the light manage to get round the corner, when it enters the camera, in order to reach the photographic plate? After passing through the lens, the light falls upon a mirror which reflects it at right angles, so that the image of the picture falls upon the sensitised plate at the back of the camera. What advantage has been gained? We have certainly not increased our light in any way, and yet there must be an advantage of some kind or other. Had the image of the picture been thrown directly through the lens on to the photographic plate, the right hand of the original would have become the left hand in the copy. The mirror reverses this, so that the picture on the photographic plate is an exact copy of the original.

Some friends remarked to me recently that they had been photographed at a country fair, and that until then they had never noticed that in a photograph one's right side became one's left side. One of the party happened to have an injured eye; in the picture it was the opposite eye which appeared to be injured. This does not really happen in ordinary photography. I have already remarked upon this fault in the old daguerreotype process, and it is bound to happen in any process in which the photographic picture is directly taken in the camera. Our glass negatives are all reversed, but they again reverse the image when printing on to the sensitised paper, so that the finished photograph is correct. The itinerant photographer who took the party referred to was doubtless making "tin portraits," which are directly produced in the camera; hence the reversal of the image.

If the block-maker were going to print directly from his negatives on to the newspaper, he would have no occasion to reverse the image by means of a mirror. But he is first of all going to transfer the photograph to a block, and on this the image will be reversed. In transferring the picture from the block to the newspaper the image will be corrected again.

The camera and the pen-and-ink drawing now being in position, the operator asks us if we would care to see him preparing his photographic plate. He finds it advantageous to use the old wet collodion process of Scott Archer, and as this process is practically obsolete for ordinary photographic purposes we are most willing to witness the preparation of the plate in the dark room. The operator takes a sheet of clean glass, and holding this in a horizontal position, he pours his collodion mixture upon it. He seems to be possessed of some magical power, for he runs this liquid all over the flat glass plate, and yet not a drop runs off the plate at the edges. Indeed, you question if the plate is really flat and not lipped at the edges. Your surprise is not lessened when the operator tilts up the plate and pours the surplus liquid off at one corner and back into the bottle, leaving an even coating upon the glass. It is difficult to realise that it was simply a molecular cohesion which prevented the liquid flowing over the edges of the plate. The plate is then placed in a bath of silver nitrate, whereupon it becomes opaque and yellowish white; it is then sensitive to light. The wet plate is then placed in the dark slide and is taken out to the camera. The pen-and-ink drawing which is to have its photograph taken is illuminated by two electric arc lamps. The shutter of the dark slide is drawn back and the cap of the camera lens removed, giving an exposure of about one minute.

Another very short visit to the dark room and the plate is developed. It has still to pass through several chemical baths, after being washed. The purpose of these is to build up a stronger image. These processes are carried on in daylight, and do not take many minutes. The visitor asks why it is necessary to work with the old wet-plate process; would not dry plates serve the same purpose? For the block-maker's purpose the ordinary dry plate is too coarse in the graining of its film, and it is difficult to make a dry plate that will give as clear a film as is obtained in the wet collodion process. The block-maker also finds the wet plate an advantage because it is more quickly developed and fixed. Besides, it only takes him a minute or two to prepare his plate; and then he can use the same glass plates over and over again. This is an advantage, as sometimes the glass plates are very large. The total cost of his chemicals is also very small compared with the price of large dry plates.

While the negative is drying the block-maker prepares the material for his block. As the picture he is reproducing is a pen-and-ink drawing in lines, it will do quite well to reproduce it on zinc, the cost of which is small. The surface of the zinc plate is polished, and after washing it is ready for sensitising. The chemical solution, which is already sensitive to light, is poured upon the zinc plate.

The operator has previously fixed the zinc plate to a small whirling apparatus, which he holds in his hand. The whirling apparatus reminds one of the mechanical egg-stirrers with which our mothers' cooks used to beat up eggs. The purpose of whirling the zinc plate round is to throw off the superfluous liquid and leave only a very thin film upon the zinc. This film represents old Niépce's bitumen coating. While the whirling operation is being carried on the plate is held over a heating stove, so that it is dry almost immediately.

Next comes the transferring of the picture to the sensitised zinc plate. This is done in exactly the same manner as one prints an ordinary photograph from a negative; the sensitised zinc plate taking the place of the sensitised paper. During the printing, the negative and the zinc plate must be pressed very close together, and to this end the printing frame is made very strong. The block-maker finds it more convenient to do most of his printing by means of a powerful electric arc lamp. After about three minutes' exposure the zinc is ready, but when taken out of the frame only a very faint image can be seen.

Niépce spoke of the image on his plates as being invisible, but Daguerre wrote a paper, in 1839, pointing out that Niépce was wrong in saying so. One might say that in any case the image is very faint, so that there seems little to quarrel about, but there is no doubt that the point to which Daguerre really wished to draw attention was that the image in Niépce's process was not a latent image to be afterwards developed by chemical means. Undoubtedly Daguerre was the first to discover a latent image, as related in an earlier chapter.

The block-maker is going to treat his zinc plate very much in the same way as Niépce treated his early heliographs, but the operator first of all inks the whole surface over with a black greasy ink. He then washes away the parts of the film which have not been affected by light and which have therefore remained soluble. This leaves an image in ink with a support of insoluble chemical coating beneath it. The greasy ink is going to act as a resister during the etching process, but before placing the zinc plate in the etching bath it is necessary to varnish the back of the zinc plate to prevent the acid attacking it. The face of the plate is now bitten into by the etching fluid, except at those parts protected by the inked film. This etching process is allowed to go on until the protected lines of the picture stand up in bold relief. The sides of these lines are protected from the acid by dusting on a powder and then heating it.

These zincotypes are just like the old woodcuts. The wood engraver drew his picture on a flat block of wood, and then he cut away some of the wood, leaving the lines of the picture standing up in relief above the body of the block. In the zincotype we transfer the picture to the block by photography, and by means of the etching fluid we "bite away" the zinc surface, leaving the lines of the picture to stand up from the block. The zinc plate is then mounted upon a strong block of wood, so that it can be properly set in the printing machine, and used along with ordinary type.

CHAPTER IX

MORE ABOUT BOOK ILLUSTRATIONS

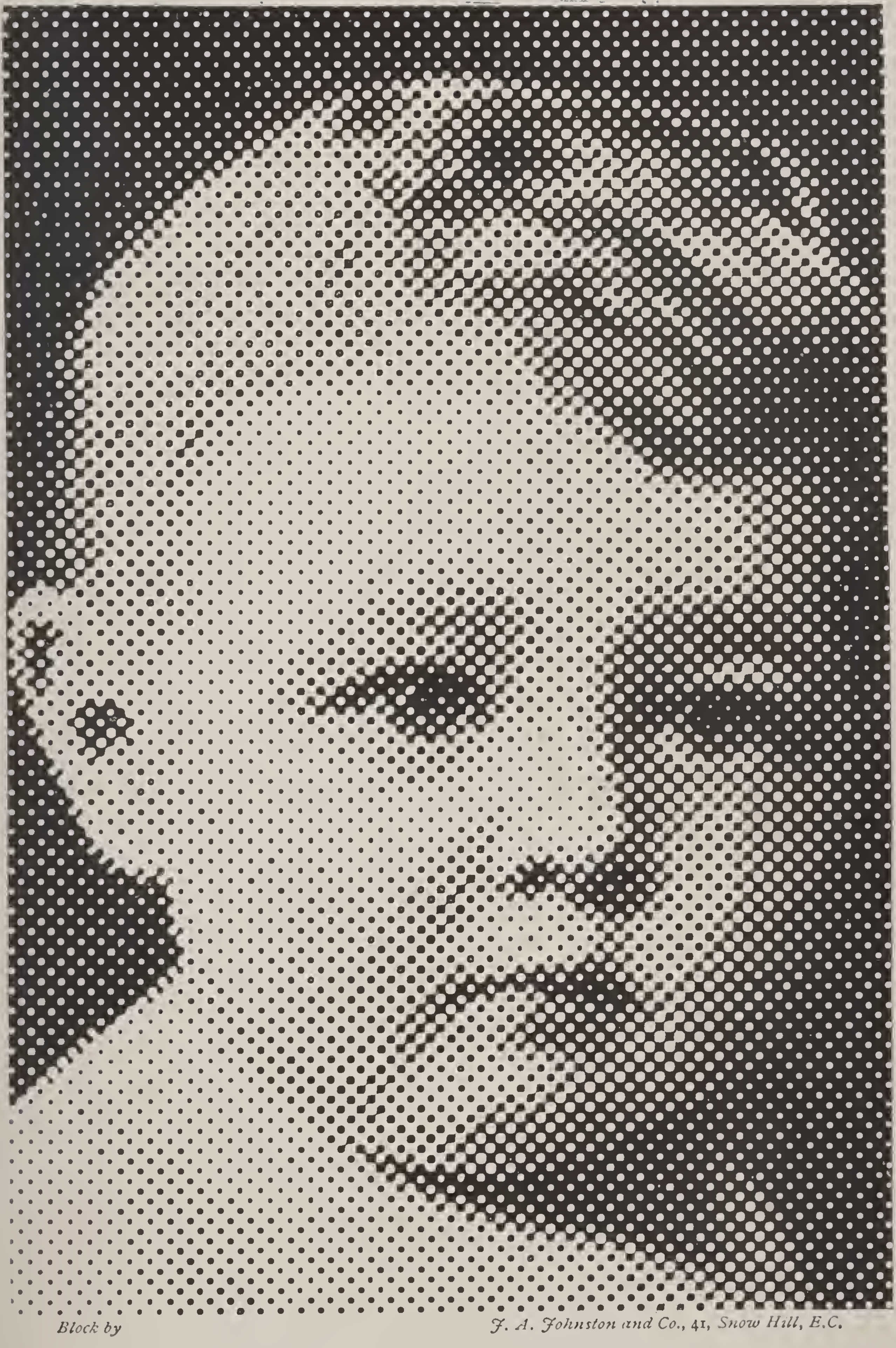
The "half-tone" process for reproducing photographs and paintings —The great artist Light—Making the negative—The use of the process screen—A myriad of photographs in one—Making the block—How the screens are made—How the block prints—Other beautiful processes—Woodburytype—Photogravure—Collotype—How photo-postcards are made.

IT will be evident that only pen-and-ink drawings can be copied by the zincotype process, described in the preceding chapter. The picture must be composed of lines or black and white patches. One could not copy an ordinary photograph, nor a painting, by this method, which is essentially a line process. A piece of music is easily copied in zincotype, and the cost of making such blocks is much less than by the older methods.

How then can we ever hope to transfer an ordinary photograph to a block, so that it may mechanically print the photograph on to paper? Suppose we do sensitise a metal plate and then print an ordinary photograph upon it from a negative. We shall have the picture upon the sensitised metal surface, but we cannot hope to etch or "bite away" all this complex variety of light and shade; we have no distinct lines. The difficulty might seem insurmountable, but it has been overcome in a very ingenious way. No doubt the idea was first suggested by some old wood-engravings made by the French engravers about the middle of the fifteenth century. Instead of merely cutting away the wood and leaving lines, these engravers introduced a new effect by cutting so that small upstanding dots remained. These raised dots were made of different diameters, in proportion to the amount of ink the engraver wished to appear upon the paper at any place. This process has been called *stippling*.

If we could only make a metal plate with a myriad of small outstanding dots which could be inked and then printed from, we could produce all shades from black to white by varying the sizes of the dots. If we made the equidistant dots of large diameter so that they almost touched each other, they would naturally receive a good deal of ink as the roller passed over them, and would therefore print a patch of black. If we reduce the size of the dots so that we shall have white paper showing through between them, the printing will be a mixture of black and white, which produces a grey effect. We may go on reducing the size of the dots until they are so small that the paper looks practically white.

If we look at a picture made of dots, as in the illustration on the page opposite, the effect is not very pleasing. If one leaves the book open at this illustration and then looks at it from the other side of the room, the effect of light and shade is really wonderful. The individual dots are no longer visible. It would hardly do to make book illustrations which required to be viewed in this manner, but it is obvious that if we make the dots so small that they cannot be seen individually by the eye, the result



Block by *J. A. Johnston and Co., 41, Snow Hill, E.C.*

HOW PHOTOGRAPHS ARE REPRODUCED IN BOOKS

This photograph has been produced through a very coarse screen in order to show the construction. Look at the picture from a distance. (See chap. ix.)

will be the same. If the dots are to be so small that one cannot see them as dots, how can we ever hope to produce them upon metal, and at the same time arrange their sizes so that we shall have all the variety of light and shade? The great artist Light can do all this for us in a few minutes, if we only place the proper apparatus at his disposal. No human artist or engraver could manipulate such small dots, and yet this great artist Light must act on each dot independently. If the reader will take a magnifying-glass and examine any of the illustrations in this book, he will see that this is no light task to perform, as the dots are set so close together that over half a million are required to produce one of the larger illustrations.

Are we then to supply the artist Light with a separate camera with which to produce each dot? I see no other way of doing it. A statement of this kind will seem to be going beyond the scope even of romance, and to be across the border-line of sense. The reader will remember, however, that the original camera obscura had no lens; it was simply a hole in the window shutter or screen. Then again facing page 316 we have an illustration of photographs taken through a pin-hole. Suppose now that we arrange a great myriad of pin-holes on a single screen, the construction of which we shall consider later. At present we shall picture it as a screen of fine black gauze or netting supported on a sheet of clear glass. We place this screen inside a large camera in the position usually occupied by the ground-glass focussing screen. We may imagine the image of a picture falling upon this gauze screen, just as we find it on the ground-glass screen. As a matter of fact, we should not really see an image under such circumstances without the aid of a focussing eyepiece, for our screen is clear glass, and not semi-transparent like the ground glass. However, the rays of light to form the image are there, as we may prove by examining any part of the screen with a suitable magnifying glass, called a focussing eyepiece. This eyepiece simply brings the light rays passing through the screen to a focus for the eye. We therefore picture all the variety of light and shade, of whatever subject is in front of the camera, as falling upon this glass screen with its myriad of pin-holes. Each pin-hole will allow a sharp pencil of light, as it were, to pass through it, and it is with those seventy thousand pencils that the artist Light is going to make a record upon a photographic plate.

We place a sensitive photographic plate immediately behind the pin-hole screen, so that the different pencils of light will fall clear of each other. We shall receive upon the photographic plate a myriad of separate impressions which, when developed, will appear as tiny dots. If the same intensity of light was falling upon all the pin-holes, then we should have a plate with dots of uniform size. We have, however, a great variety of light and shade, so that there will be very energetic pencils of light passing through some pin-holes, weaker ones through other holes, while there will only be a very faint pencil of light through those parts which are in shadow. When the plate is developed we shall find that where a strong light has come through a pin-hole there will appear a comparatively large impression or dot. Where a fainter light has passed through a pin-hole there will be a correspondingly smaller dot.

Suppose we wish to make a dotted negative from a photograph of a man. We set up the photograph in the same position as we had the pen-and-ink drawing in when making the negative for the zincotype block. The only difference now is that we are going to interpose the gauze screen in front of the photographic plate. Without going into details, we may picture a strong light being reflected from the man's face, so that energetic pencils of light mark the plate at the place where an image of the face would fall. We therefore have a series of large dots on the negative at this place. The man's black coat reflects very little light, hence small dots will represent the image of the coat upon the negative. It is the negative we are considering; the dots will be reversed when transferred by light to the block. A glance at the illustration opposite page 128 shows large dots producing the dark objects, and smaller dots the lighter parts.

The preparing of the wet plate, the taking of the negative, and its subsequent development are all identical with what has already been described in connection with zincotype, with one exception—the introduction of the gauze screen. Having obtained our dotted negative, we may leave it for a little to consider how the pin-hole or gauze screen is made.

Some of the screens, for fine work, will have four and a half million pin-holes in one square foot. How will it be possible to make such a myriad of holes so close together? The method adopted is very simple. The screen is made up of two sheets of glass, each being covered with a series of parallel lines lying diagonally across the glass plate. When the two plates are mounted, with their ruled faces together, the two sets of lines are at right angles to each other, so that they form a gauze or net effect, as represented in the accompanying diagrams.

The method of making the screens is of interest. If two hundred parallel lines have to be ruled in one inch, it will be apparent that the lines must be very fine. The glass is first of all given a chemical surface, or film, which will resist the action of an etching fluid. The necessary lines are then cut into this chemical composition by means of a dividing machine, thus laying the glass bare along these lines. When the prepared glass plate is now put into a special etching bath containing fluoric acid, the fluid eats into the glass along these exposed lines. The result is a series of very fine grooves in the glass. These are then filled in with a black enamel, thus producing a screen covered with very fine parallel lines in black.

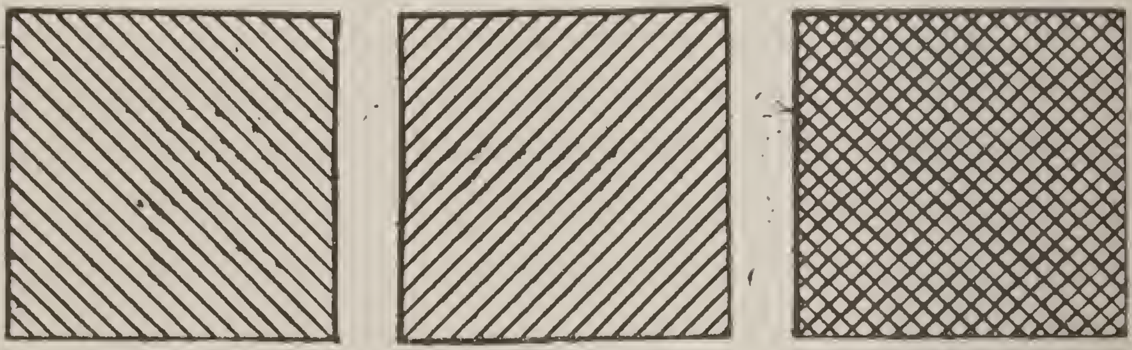

No. 1 No. 2 No. 1 and No. 2 mounted together

Fig. A
THE CONSTRUCTION OF A "PROCESS SCREEN"

A second screen is made identical with the first one, the lines running in the same direction. Then when this second plate is turned face downwards upon the top of the first, the two sets of lines will cross each other and form the network of small holes. It will be apparent that, in the accompanying diagram, No. 1 is shown face upwards, but No. 2 with its ruled face downwards, ready to place on the top of No. 1.

A very coarse screen, say for poster work, may have only fourteen lines to the inch. The illustration opposite page 128 has been taken through a sixteen line screen, whereas the majority of the illustrations have been made through screens having 175 lines to the linear inch.

Having already prepared his dotted negative, the blockmaker proceeds to make a block for the printer. He takes a plate of copper this time instead of zinc, because it is more durable and gives a more perfect and a harder surface. The surface of the copper is sensitised and then a photographic print made upon it, through the dotted negative. The copper plate is then washed to remove those parts of the film which have been unaffected by light. The plate is then baked at a high temperature in order to harden the film. It is next placed in the etching bath. The surface of the copper plate is bitten away, leaving only a myriad of small dots of varying diameters. This biting away is continued until the small dots representing white in the picture have almost disappeared. After the plate is well washed it is mounted upon a block of wood and made ready for the printer, who may print with it in his high-speed machines just as though it were ordinary type.

It is, indeed, remarkable that when this seemingly smooth block is inked by passing under a roller in the ordinary way, each separate tiny dot is able to transfer an image of itself in ink on to the paper. The dots are all very small and very close together, giving the appearance of a perfectly smooth surface, so that one would not be surprised if only a very smudged effect were the result of printing. Each illustration in this book is a witness to the fine work performed by those little dots. When we consider that these tiny dots are practically invisible to the unaided vision, is it not wonderful that they can act like type and print thousands of copies of those beautiful photographs?

It is interesting to note that the block-maker can vary the shape of the small dots upon the negative, which in turn determines the formation of the dots upon the metal block. We may picture each space in the ruled screen as acting like a pin-hole camera and giving an image of the aperture of the lens of the large camera. The operator may therefore insert diaphragms, with differently shaped openings, in front of the lens. If he uses a diaphragm with a square opening, then the little dots will all be square, and so on.

In the earlier part of this chapter we saw how line drawings are transferred to the printer's block by means of photography; the process being called zincotype. Then we have just been considering how paintings or actual photographs may be reproduced by means of *process screens.* This process is descriptively named the *half-tone process.* I have gone into the particulars of these at considerable length, because they are the two processes most commonly in use at the present time. The one great advantage, in these processes, is that the printing surface stands up in relief, so that the zincotype and the half-tone blocks may be used along with ordinary printing type. The rate of production in printing is therefore very great, and the cost correspondingly small.

We have already noted that when a printing surface is not in relief, but has its lines sunk below the surface of the plate, as in the copper plates engraved by hand and in the early heliography of Niépce, the process is known as *intaglio.* This is an Italian word meaning to carve or cut. It will only be possible to give a very brief description of a few well-known intaglio processes. It will be well to include this description, for if the inquiring reader examines illustrations in different books with the aid of a magnifying glass, he may be puzzled when he comes across an illustration which it is clear is neither a zincotype line block production nor a dotted half-tone.

The most perfect of intaglio processes is one known as woodburytype, being so called after its inventor. Here we have the original idea of Niépce appearing again. A preparation of bichromated gelatine takes the place of Niépce's bitumen. This prepared photographic plate is exposed to light under a negative, and the gelatine is then dissolved away, its solubility being in proportion to the amount of protection offered it by the negative. A mould is therefore formed in the gelatine, the deepest parts being under the dark portions of the negative, and the shallowest parts being under the most transparent portions of the negative. Now comes a most remarkable part of the process. If this gelatine mould be placed in a hydraulic press, with a sheet of lead over it, and an immense pressure equal to about four tons to the square inch be applied, a clear impression is left in the lead. This lead mould is, of course, a reverse of the gelatine mould; the projecting gelatine is now represented by a depression in the lead mould, and the sunken portions of the gelatine stand up in relief upon the lead. Let us trace the process by looking at a white object in the original picture which is being copied. The white object appears as a black patch upon the photographic negative. This opaque patch protects the gelatine when it is exposed to light, so that, on being washed, the gelatine at this part will be dissolved and there will be a consequent depression. The hydraulic press will force the lead into this depression, producing the same formation in relief upon the lead; this now represents the white object in the original picture.

From what has been said, it will be clear that the variation of light and shade in the original picture is represented by variations in depth of mould in the lead. If a warm gelatinous ink be now poured into the lead mould and a well-sized paper be firmly pressed down upon it, the paper will lift out the whole of the ink. The ink will be thickest at the greatest depressions and least at the shallowest parts. In this way a beautiful copy of the original picture is reproduced with very perfect gradation of tone. It will be quite evident, however, that this process must be a very slow one compared with the half-tone process, which is printed like ordinary type.

We have seen, in this woodburytype process, that a gelatine mould is able to impress all its variations of depth upon a sheet of lead. It is very surprising to learn that after this gelatine mould has been subjected to an immense pressure, which would be equivalent to about one hundred tons for an illustration to suit this page, the gelatine mould remains uninjured and ready to produce further lead reverses if desired.

Another important intaglio process is that known as *photogravure*, which reproduces the shades of the original with great artistic effect. I saw some illustrations being made recently, by this process, for a book on birds. It was really very difficult to detect any difference between the artist's black-and-white drawing and the printer's photogravure. One could have believed that every copy had been specially drawn by the artist. How is this interesting feat accomplished?

First of all the photographer photographs the artist's drawing. From the resulting negative a positive is taken on a surface of bichromated gelatine, or as it is more commonly called, a *carbon tissue.* When this exposed carbon tissue has been washed, there remains a mould of varying depths, as described in the preceding process. This gelatine film is floated off its support and transferred to a copper plate, which has been previously treated with bitumen dust to give it a grained surface. The gelatine film is transferred to the copper plate before being washed. The plate is next placed in a bath of etching fluid, which can make its way through the gelatine and attack the metal plate. It naturally gets through the thinnest parts of the gelatine first, and bites in to some depth at such places before it has reached the plate through the more dense parts of the gelatine. The action is allowed to go on until the fluid just commences to act on the places under the thickest gelatine. The copper plate has now been etched, and the result is a very much more perfect representation of the different tones of light and shade than the most expert hand engraver could produce.

The engraved or etched plate is then given a thin electro-plating of iron to produce a harder surface than the copper. It is now ready for the printer, who inks the plate all over by hand, and then cleans the ink away from the surface, leaving the sunken image filled with ink. When a suitable paper is pressed firmly down upon the plate, by means of a hand-press, the ink is transferred from the depressions to the paper. The result is a beautiful picture very closely resembling the artist's original drawing. The production of photogravures is necessarily slow and costly, the inking of the plate and the printing requiring to be done by hand. Recently a process of printing photogravures by machine has been invented, but is not in general use.

Another interesting process belonging to the same class, but depending upon a different principle of printing, is called *collotype*. The bichromated gelatine is exposed and treated in the usual way. The parts which have been exposed to light will not only become insoluble, but by a special treatment the surface is divided up into a grain—a process known as reticulation. This will vary in proportion to the amount of change produced by exposure to light under the negative. If we now pass a roller with greasy ink over the plate, we shall find that the grained surface will print the different tones. In this way the collotype block can transfer the required amounts of ink to paper and produce a picture very closely resembling the original photograph.

Photography has been applied to the production of illustrations in many other ways, but I fear further details might become wearisome. The processes we have already considered are those in most common use. I think it will be of more general interest if we now inquire how photography has enabled us to produce those beautifully coloured pictures by what is known as *the three-colour process.*

Before closing this chapter it may be of interest to consider the making of photographic post cards.

The present is the day of pictorial post cards. The handling of these alone by the Post Office is a great undertaking. There were hundreds of millions of these sent through the post last year; probably not less than one million per day.

Pictorial post cards are not all made by photographic processes, but a very large proportion are, either directly or indirectly. Surprisingly large quantities are actual photographs printed directly on to sensitised post cards. This is not merely a hobby with amateur photographers, but is also done on a large scale commercially. Small machines are made whereby the printing of these may be carried out very expeditiously.

There are many cases of amateur photographers paying their holiday expenses by making picture post cards of local interest. A direct photographic post card will sell retail at threepence, and if the amateur gets twopence from the shopkeeper, then rather more than half of his takings will be clear profit. But what about the time required to produce the cards by hand? A simple calculation on the foregoing basis shows that the amateur must turn out over two thousand cards to earn ten pounds. Imagine printing two thousand photographs! It does seem a serious undertaking, and yet amateurs have accomplished this. Specially rapid bromide post cards are made, which require only an exposure of one second to the light of an incandescent gaslight. The latent image is developed afterwards.

Here is a note given by one authority of the time required to produce fifty post cards. With suitable apparatus the printing will occupy ten minutes, developing and fixing twenty minutes, "squeegeeing" fifteen minutes, which makes in all about forty-five minutes. The prints have to be washed for about an hour, but as that process is automatic it need not be included. If handling a batch of one hundred post cards at one time, they may be completed within an hour. If this rate of production could be kept up, the amateur photographer would be earning over eight shillings per hour. He would probably require to turn professional to find an outlet for his productions.

All the direct photographic post cards, however, have not been printed and developed by hand. One company possesses an automatic machine which can print and finish real photographs "by the mile." The actual working of the machine is a trade secret, but its general principle may be described here. A large roll of sensitised bromide paper, wide enough to take in many photographs across it, is placed in a large machine. At one part of the machine a number of photographic negatives are firmly fixed in a strong frame. The machine feeds the paper forward, then presses one portion against the negatives, while a short exposure is made to artificial light. The machine then carries the paper forward to the developing and fixing baths, and finally passes out the finished photographs. The whole processes are continuous and automatic.

A large quantity of picture post cards are made by the half-tone and by the collotype processes.

CHAPTER X

THE THREE-COLOUR PROCESS OF PRINTING

Taking the negative—Making the block—Mixing of coloured pigments—We do not make colours—What the artist does—Why his fundamental colours are not the same as the primary colours—Addition and subtraction—An experiment in colour subtraction—A simple illustration—A convincing experiment—How the artist's fundamental colours are determined—An unnecessary confusion—The printer's inks—Another lantern demonstration—Three-colour printing dependent upon photography—Printing the picture—A simple case—The effect of each block—Entirely subtraction—Achievement of the artist Light—Some interesting points about the blocks—Ideal colour photography—What is the four-colour process?

COLOURED pictures have been made by the lithographic press or machine for quite a long time now. Each colour appearing in the picture requires a separate stone or block. One stone carries those parts of the picture which are to be printed in red, another those parts which are to be green, and so on. Each colour has its separate stone with its particular part of the picture. By this means a coloured picture is patched together by lithography.

When it became possible to transfer photographs to blocks by means of the process screen, as described in the preceding chapter, there was a natural desire to reproduce photographs in colours. If we think of all the different processes of colour photography with which we have already dealt, we have no hesitation in selecting the Sanger Shepherd process as a possible solution of the printing problem. It will be remembered that three separate negatives were taken in this process. One of all the red rays, another of all the green rays, and a third of all the violet rays, thus recording all the colours in the objects being photographed. A lantern slide was produced by making three positives or transparencies from these negatives, and then dyeing each transparency a particular colour, and placing one on the top of the other.

Suppose we now take the three separate negatives, and instead of making the transparencies, we make three separate half-tone blocks, one from each negative. The ordinary negatives will not serve our purpose; we must take them through the process screen in order to get the little dots, which will stand out in relief upon the printing plate. It will be obvious that there are two ways of obtaining the desired negative.

Suppose we are going to reproduce a water-colour painting. We may, first of all, photograph it through a red glass, and at the same time we may insert the process screen in the camera, so that the negative representing the red in the picture will appear in little dots. We may then do the same for the green and the violet negatives. Another way of securing the dotted negatives is to take ordinary negatives through the colour filters, and print positives of these in the usual way. Then each of these positive prints has to be photographed again through the process screen in order to obtain the dotted negatives.

Having obtained the three dotted negatives, which together represent all the colour in the picture, we proceed to make a separate half-tone block of each. If we examine these three blocks, we shall find that they are quite different from simple colour blocks, on which one part of the picture appears on one block, and another part on another block. Here we have a continual overlapping; indeed, each block seems to include almost the whole picture in some degree. A brown object is clearly seen on all three blocks. It will be obvious that we intend printing one colour on the top of the other.

From what has been said already in connection with colour photography, it will be clear that we do not propose to print from these blocks in the three primary colours—red, green, and violet. We remember that the mixing of coloured pigments is not the same as the blending of coloured lights. The former is a case of subtracting colours from white light, whereas the latter is a simple case of adding coloured lights together.

Before attempting to print a picture from these three blocks, it will be well worth our while to consider the mixing of coloured pigments, dyes, or inks. There is often some difficulty in clearly understanding the difference between the mixing of pigments and the blending of coloured lights. A purely scientific explanation is of little assistance to the general reader, and I have no hesitation in asserting that the difficulty does not exist in the minds of unscientific people alone. There seems to me to be only one way in which the general reader may easily grasp the subject and thereby dispel all confusion. He must expel from his mind altogether the idea that in mixing pigments, dyes, or inks, he is *making colours.*

Our whole stock of colours lies around us in white light. All we can do is to sort out the different coloured rays contained in white light; every colour that has at any time been produced has simply been a manipulation of light. That is where the artist got all his colours. Some one may object to this statement, and say that the artist really procures all his colours from the artist's colourmen. He undoubtedly purchases his paints there, but these are merely pigments with which he can manipulate the colours which are already blended together in the white light falling upon his canvas. If an artist friend disputes the point, we ask him to look at his paint-box by the light of a mercury vapour lamp, or if that is not convenient we make up a sodium light by mixing some ordinary salt in methylated spirits, as we did in an earlier chapter. We then ask the artist where his red paints have gone. These paints are now colourless, and yet their chemical or physical condition has not changed. There is no red colour simply because there are no red rays in the light which is falling upon the pigments. Perhaps I have pressed this matter far enough, but I am anxious that it should be perfectly clear that the mixing of so-called colour pigments is merely a manipulation of ordinary light.

Some one may say at this point that he sees quite clearly that the pigments are merely absorbing certain colour rays and reflecting others, but he cannot see why red, green, and violet should not be the primaries when dealing with pigments just as with coloured rays of light. Surely he has forgotten for the moment that the mixing of the pigments is merely the manipulation of the colour rays already existing around him. Certainly there are only three primary colours, and these are red, green, and violet. The artist may have three fundamental or primary pigments, but that is quite another matter; he is only going to use these for manipulating the three primary colours contained in white light.

Why should red, green, and violet paints not give the same result as is got by blending three lights of these colours together? The matter is really very simple. Let us take a piece of white paper; there on the paper we already have the whole stock of our colours reflected in white light. Some reader may consider that the colours are only there "theoretically." We assert that the colours are there in reality. We let a beam of light fall upon the paper, passing through a glass prism on its way. We at once see all the colours of the rainbow. We point out the three primaries—red, green, and violet—remembering that the other colour effects may be produced by different combinations of these three colours. If we withdraw the prism we see no colour, but the colours must still be there. It is only when our three colour sensations are simultaneously stimulated that we see white. We are bound to admit that the colours are really there upon the white paper.

Suppose we cover the white paper with a red paint, what have we really done? We have applied some substance which has absorbed, or blotted out, all the green and violet rays of the white light, leaving only the red rays to be reflected to our eyes. We have nothing left on the paper but the red rays. There we say we have our first primary colour, and we are going to attempt to

Richard Cœur de Lion and his Fleet on the way to the Holy Land.

The Three-Colour Process of Printing.

The above shows the three separate printings which when printed one on the top of the other produce the complete picture. The blocks are prepared by photography, as explained in Chapter X. The above illustration has been taken from *The Crusaders*, by Professor Alfred J. Church.

combine red, green, and violet to produce white, just as Ives did in his triple-lantern process. We next take some green paint, or transparent dye, with which we can overlap the red on the paper. We know that this green dye will cut off the red and the violet rays, but our paper is at present only reflecting red rays, so that a transparent coating of green will cut off these red rays, and we shall have no rays at all reflected from the paper; it will therefore appear black.

It is now quite clear that the mixing of coloured pigments is different from the blending of coloured lights, but some reader might still like to ask why there is a difference. I think there can be no simpler definition than that already given; the blending of coloured lights is a case of *addition*, whereas the mixing of colour pigments or dyes is a case of *subtraction.* The artist often wishes he could add light as he puts his coloured pigments upon the canvas.

Take as an illustration of the first case Ives' three lanterns independently throwing red, green, and violet lights upon the lantern sheet, so that they fall one on the top of the other. Suppose we have the three lanterns all ready with their respective colour screens or filters in position, but we have a shutter over each lens. Ives therefore starts with no colour—darkness—on his lantern sheet. He first opens the one lens and throws red upon the screen; he then adds green to this, and the two lights overlapping or blending together produce the sensation of yellow. He then adds violet light on the top of the red and green, when all three together produce the effect of white. Our whole three sensations are simultaneously excited. This has been a clear case of addition; we started with a blank sheet—darkness—and we added the three primary colours together.

In the second case, the mixing of coloured pigments, we set off with all three colours—white light—reflected from a piece of paper. We apply a red dye, and thereby we blot out the green and violet rays, leaving only red. That is quite a big subtraction already. We then add a green dye, which absorbs the remaining red rays, and we have nothing left. It is a clear case of subtraction.

In describing his process of colour photography Sanger Shepherd has said that his method is one of subtraction. This has no doubt been said in order to differentiate it from Ives' process. But is not all colour manipulation a case of subtraction? I believe that any other way of looking at the matter is sure to lead to confusion. We can only have an addition where we have separate individual lights, such as in Ives' triple-lantern process. As long as we are painting or printing on white paper or other substances, we are merely manipulating the colours already contained in white light, and our manipulation must necessarily be one of subtraction.

Let us take a very simple illustration. We have a new wooden door, and we send for the house painter to come and paint it red. The painter does not really bring the red colour with him; the colour is already there, reflected from the door in white light, before we ever sent for the man. The door is reflecting red, green, and violet rays blended together, and producing the sensation of white. What the painter really does is to apply a substance which will absorb or subtract all the green and violet rays, leaving only the red rays to excite our vision. Some one may suggest that we are taking a very roundabout way of thinking; he would prefer to speak of simple addition. Why, you can see the red stuff in the painter's pail, and you see the painter add that to the door. Certainly we see the "red stuff" in the pail, because the property of that substance is to absorb the green and violet rays of light, and reflect only the remaining red rays. But we are forgetting again that the red colour is not an inherent property of the substance in the pail. But as the painter only exists in imagination, we can afford to detain him without fear of running up a big wages bill.

We take the painter indoors. We close the window-shutters and light the gas or turn on the electric light. We ask him to look at the red stuff in the pail; it looks very much the same as before. We then prepare a sodium light, as we have done on two previous occasions, by mixing salt and methylated spirits together. As soon as we have set a light to this mixture we turn off the gas or electric light, whereupon the red stuff in the pail is no longer red. This particular painter happens to be rather a duffer, and he blames me for spoiling his pot of good paint. I relieve his distress by extinguishing the sodium light and turning on the gas or electric light, or by opening the window-shutters. He once more sees his paint red, and he is quite satisfied that no chemical or physical change took place in the paint-pot. I fear he goes away only mystified and not enlightened.

I tell an artist friend that, before he ever puts a brush to his canvas, all the colours he is going to have are already there upon the canvas. I fear that, unless he has a scientific mind, he will think I am merely making fun, or that I require a mental rest. It is none the less true; the artist merely mixes his pigments together, and thereby subtracts the green and violet rays from one part of the canvas, leaving the red rays to be reflected to the eye, and so on.

It is clear that the artist's fundamental colours must be different from the three primaries with which we have been dealing, but how are these colours determined by the artist? The artist has long known that if he has what are usually called red, yellow, and blue paints, he can mix these together and produce practically any desired colour and shade. Indeed, it is common practice for the artist and the colourman to call these the three primary colours. Hence arises considerable confusion. It is quite right that they should call these their three fundamental or primary paints, but I most emphatically protest against the practice of calling these the three primary colours. There are but three primary colours—red, green, and violet. The primary red pigment is not the same as the red of the spectrum, and the same applies to the printer's ink.

The printer's three inks should really be the yellow, greenish blue, and crimson-pink, as used in colour photography (Sanger Shepherd process), but in practice they differ considerably, so that we shall merely call them yellow, blue, and red inks. The red ink does not only reflect the red rays of light; it also reflects the violet rays of light, causing these two colour sensations to be excited. Our primary red colour, on the other hand, affects the red sensation only. In the same way the printer's blue ink reflects both the green and the violet rays of light, while our primary violet colour affects only the violet sensation. Therein lies the whole difference, and it cannot be said that it is merely a theoretical difference.

The printer's third fundamental or primary dye is *yellow.* This dye or ink reflects both red and green rays of light, and the simultaneous excitement of these two sensations produces the effect which we recognise as yellow.

The artist and the printer know that these three primary paints or dyes will enable them to produce practically every colour, but what is the reason underlying this fact? Think again of the white sheet of paper. There we have every colour we can ever possess. The colours are blended together to form white light. Now in order that we may manipulate this combination of red, green, and violet rays to full advantage, we must be able to subtract each colour separately at will. Red paint, corresponding with the red of the solar spectrum, subtracts both the green and the violet rays, leaving only the red rays to affect our vision. What we want is a pigment or dye which will subtract only one, and leave the other two primaries intact. The experiments which we made in order to help us to understand the Sanger Shepherd process of colour photography will be of service again.

We take three separate lanterns, and by placing a red glass screen in one lantern, a green screen in the second, and a violet screen in the third, we cause these three coloured lights to fall one upon the other on the lantern sheet. The sheet appears white, or at least practically so, for it is difficult to get our colours of exactly the right hue. Let us now subtract one of these primary colours. Suppose we cut off the light from the violet lantern, and leave only red and green to overlap upon the sheet, we shall then see the sheet yellow. A yellow ink will therefore subtract only the violet rays from white light. If he prints yellow ink on to a paper, he merely subtracts the violet rays of light.

We then set all three lanterns once more, whereupon we see the sheet white. This time we cut off the green light, and there we have a crimson-pink sheet. A crimson-pink or red ink therefore subtracts the green rays. Once more all lanterns alight, and we have a white sheet. On this occasion we shut off the red light, thus causing the sheet to appear a greenish blue. Greenish blue or blue ink therefore subtracts the red rays.

We shall stick rigidly to the idea of subtraction. To sum up: yellow ink subtracts violet, the red ink subtracts green, and the blue ink subtracts red. Some readers may think that I have forgotten that my subject is photography, I have written at so great a length upon the subject of colour, but I see no other way of explaining the three-colour process. If we did not first of all fully grasp the meaning of colour, we could only form a very imperfect notion of the three-colour process.

This interesting process of printing coloured illustrations is dependent upon photography. It is by means of the camera that we can make the necessary printing blocks. As we have dealt with the making of the three blocks in the early part of this chapter, it only remains for us to see how the colours are reproduced on paper. Let us take the very simplest illustration: a violet flower and green leaves in a red vase, the background being black.

The printer finds it necessary to print his yellow ink first, as it is not so transparent as the others. Then he prints his red ink on the top of that, and finally his blue ink on the top of these two.

It will be remembered that we have already prepared a block to subtract violet from every part of the picture except where it is wanted. We only wish violet in the flower, and so we print yellow (which subtracts violet) over the whole paper except for the flower.

If the reader turns to the coloured illustration facing page 154, he will see a simple demonstration of three-colour work such as I am describing.

We start with our whole stock of colour on the plain white paper. This first block (yellow) subtracts violet rays, the second block (red) subtracts green rays, and the third block (blue) subtracts red rays. Therefore, where-ever the three blocks print, one on the top of the other, we subtract red, green, and violet, which is our whole stock. Hence we leave the background in our illustration without any colour (black).

Our first block leaves the flower in white, which means red, green, and violet, but the other two blocks subtract the green and the red respectively, and therefore leave only violet to be reflected, as is seen in the complete picture at Fig. B.

The leaves are left white by the second block, but the other two blocks rob them of violet and red rays, leaving only green rays, as seen in the complete picture.

The vase is left white by the third block, but the other two blocks rob the vase of violet and green rays, so that red alone is left to be reflected.

Our picture is complete—a red vase, green leaves, and a violet flower—but what a very roundabout way of producing it! Why not simply print the vase red, the leaves green, and the flower violet? It must be understood that this picture is merely explanatory; no picture is so ideally simple as to contain only objects of the three primary colours. From Fig. C it will be seen how the three printing inks overlap and produce those colours, making in all six colours and black. But this is not all, for the half-tone blocks can vary the proportion of each colour and thus produce endless variety of shade.

It will be remembered that the block made from the photograph taken through the red screen does not merely record red objects, but also the red rays contained in any other compound colour, and so on. The infinitely complex variety of colour is first of all analysed into the three primaries. We then make these three records subtract the three primaries from white light in the required proportions to reproduce the original picture. The records could not be made by the hand of man; it is only the great artist Light who can satisfactorily make these records by photography.

The printer has to take great care that his second printing exactly overlaps the first, and so on. If there is any imperfect overlapping of the blocks, the picture is imperfect.

There is another point of interest about the dotted

Simple Demonstration of Three-Colour Printing.

See page 153.

blocks. If two pieces of fine muslin or net are laid one upon the top of the other there is produced a moiré effect, such as is seen on "watered silks." The experiment is worth trying. If one of the pieces of muslin is turned round so that its threads are at an angle to those of the other piece, this moiré effect disappears. If the block-maker took his three negatives through screens with the lines all lying in one direction he would be troubled with this moiré effect when one block is printed on the top of another. He therefore uses different screens, on which the series of lines are at different angles to each other. If one takes a magnifying glass and examines the dots on the three-colour picture opposite page 146, one will see the lines of dots of each block have been at different angles.

The majority of illustrations made by the three-colour process are reproductions of paintings, but many beautiful illustrations of still life have been made direct from nature. The three-colour process of printing is really the nearest approach to natural-colour photography. If our colour screens or filters for taking the three negatives were absolutely pure spectrum colours; and if our photographic plates could record and reproduce the exact proportions of the different coloured rays; and if each printing ink could perfectly subtract its own primary colour and nothing else: then we should have a natural-colour photography. But we have three "ifs" in the preceding sentence, and doubtless a few more might be added. It reminds one of the old nursery rhyme:—

> If ifs and ans were pots and pans,
> There'd be plenty of work for the tinker's hands.

The photographer, the block-maker, and the manufacturer of printer's inks are already doing good work, and without a doubt they will advance still further.

Think of the advance already made by the three-colour process. In ordinary lithographic printing, sometimes the printer has occasion to use as many as twenty different stones or blocks in order to build up his coloured picture. Photography enables us to get every variety of colour from three blocks, and the results stand head and shoulders above the older methods.

What about the four-colour processes? The fourth block is usually printed in a neutral colour, or in black, and is merely to add depth to the picture, or to try and neutralise some of the shortcomings in the combination of the other blocks. As far as we are concerned this is a technical detail, so that the subject does not interest us. Sufficient detail has already been given to enable us to appreciate the triumph of photography in colour printing.

CHAPTER XI

PHOTOGRAPHY AND THE CRIMINAL

Misleading photographs—The criminal's disguise—Novel use of a photograph—The use of photography by the police—An early photograph of criminals—The true use of the finger-print system —An amusing cartoon—Disguise defeated—The "Kathleen Mavourneen" act—Method of taking the finger-prints—Detection by tell-tale finger-marks—Interesting cases—Photographic enlargements—Forged documents.

PHOTOGRAPHY plays a very important part in the detection of the criminal. It is true that a photograph is often very misleading; the portrait of one man might easily be mistaken for that of another. In the illustration facing page 118 we have portraits of three different criminals, any one of which might be mistaken for the other. A portrait therefore cannot be used as a proof of identification. As a matter of fact, the photograph taken of a criminal at the time of his dismissal from prison may have no apparent connection with a photograph of the same man taken a few months later. A good illustration of this fact has been given me by the authorities at New Scotland Yard, London; this is shown opposite page 108.

In this illustration there are only five different men's photographs, but there are two photographs of each man, the pairs of portraits being distinguishable by the manner in which they have been mounted. It is a curious fact that the photographs in the lower row were all taken some time after those in the upper row. Take, for instance, the second man. His photograph shows him as an elderly gentleman, with grey hair and grey beard. When he fell again into the hands of the authorities, some twelve months later, his appearance was that of a much younger man, with black hair and black moustache, as shown in the lower illustration. It would be quite impossible to identify these five men by means of their previous photographs. We shall see later how the finger-print system is a sure means of identification.

I recollect a case in civil life where a photograph was used in place of the name upon a postal packet. An amateur had photographed a regiment of soldiers as they left for South Africa at the time of the Boer War. The photograph turned out to be a very good one, and the photographer was sorry that he did not know any one in the regiment to whom he might address a copy of the picture; indeed, he did not even know the name of the regiment. He adopted a novel method of addressing the packet containing some copies of the photograph. Selecting one of the men, whose face was very clear, he cut this man's photograph out of one of the copies, and gumming it to the front of the envelope, he simply addressed the packet:—

"To (photograph),
Serving in the Field,
South Africa."

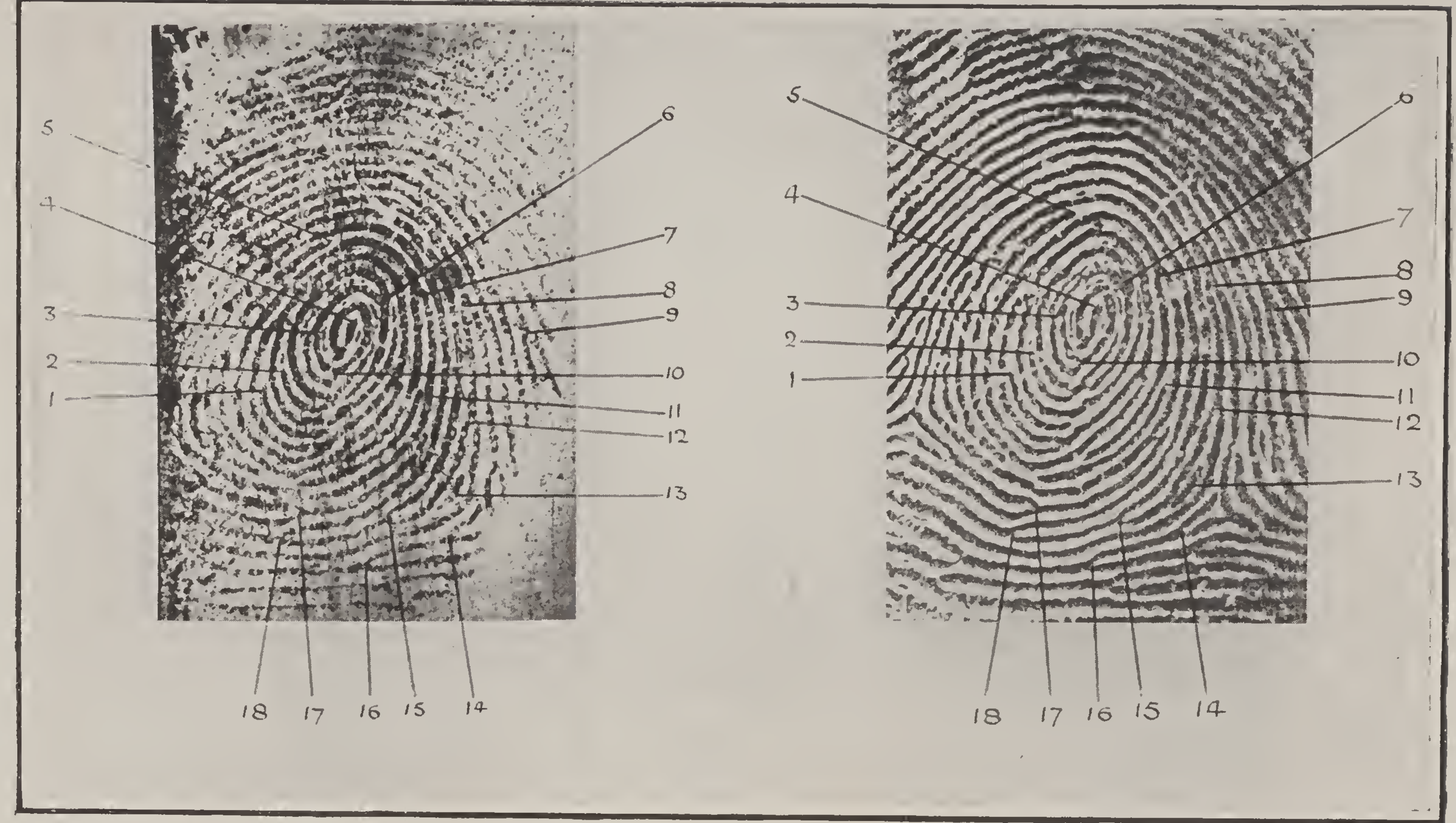
The packet reached its intended destination in safety. No doubt the military authorities could tell the particular regiment from the photograph shown, and those commanding the regiment were able to hand the packet to the man whose photograph was exhibited on the outer cover.

Although the criminal may disguise himself, the police authorities continue to photograph their prisoners, and these portraits very often help them to lay hands on some one that is "wanted." They take both a full-face portrait and a profile, and then place the two together on one card. At some police centres only one photograph is taken, but this shows the full face and at the same time the profile in a looking-glass in the picture. The effect is not so natural as that of the two separate photographs, and the looking-glass has been abandoned at headquarters, two separate photographs being taken.

Word may be sent to Scotland Yard from some distant town informing them that some mischief is being done, perhaps on a large scale. From the description of the methods adopted in the crime, the authorities may suspect that it is the work of one or other of a certain class of known criminals. The portraits of these suspected persons are looked out and sent down to the distant town, no mark whatever being put upon the photographs. Inquiries are made in the neighbourhood as to whether any of those men in the photographs have been seen going about. Perhaps quite a number of people recognise one particular portrait as being very like some one they have seen lately in the town. This helps to put the authorities on their guard, and will enable the police to keep their eyes upon the suspected person.

Then again the police in one district may want a particular criminal, but he has fled the town. Copies of his portrait are sent out to other centres, so that a look out is kept for the "wanted" man. Every police centre has its portrait "gallery" or album, with the contents of which the detectives seek to become familiar. The detectives have good memories for faces; that is part of their everyday business. Passing along a busy street, a detective observes a stranger whose face has been imprinted upon his memory by means of a photograph. He cannot tell for what or by whom the man is wanted, but he is so sure that he is wanted somewhere that he has the man arrested and taken to the police station. After lodging the man in a cell as a suspected person, the detective consults his "gallery" of photographs. At first he cannot find out where the man is wanted. Several times he brings the man from the cell to compare him with some photograph, the prisoner submitting good-naturedly, "quite sure the detective has made a mistake." At last the detective does find the portrait he wants, and on showing it to the prisoner he acknowledges that the game is up. The real criminal may be said to behave in quite a gentlemanly manner when he is cornered. Unfortunately he looks upon his crime as his business; he tries all possible means to evade the police, but when he is caught and identified, then he has played his last card.

In the illustration facing page 58 is shown the first photograph of criminals taken in Glasgow. This photograph has already been referred to in another chapter as an



By permission of the authorities at New Scotland Yard

FINGER-PRINTS ARRANGED FOR POLICE-COURT CASE

The left-hand illustration is an enlarged photograph of a tell-tale finger-mark left by a criminal upon a piece of glass. The right-hand photograph is a similar enlargement of the criminal's thumb-print taken on paper. Eighteen identical points have been marked off to prove to the judge and the jury that this particular prisoner left the thumb-mark on the glass. (See chap. xi.)

illustration of Scott Archer's positives on glass. This photograph is made up in a little frame just as the daguerrotypes were, and on the back of the frame there is an inscription which reads:—

"No. 1. James Martin Lindsay, dirty thief.[1]
No. 2. James Brown Cummings, pickpocket.
No. 3. Peter Hasson, pickpocket.
No. 4. John McCrae, tailor (associate of thieves)."

Unfortunately there is no date upon this photograph, but there is no doubt that it was taken at least half a century ago.

We have seen that, despite the unreliability of a portrait, photography does serve a useful purpose in the detection of the criminal. Even if the criminal has disguised himself considerably, there is often a drooping lip, a cocked nose, or some particular formation of the head which points the man out to the watchful detective. The proper value is thus put upon portraits by the police. They cannot bring forward a photograph of a person previously convicted, and say to the Court that the present prisoner is the same man as was convicted for another crime. This would be a dangerous practice. Some one might be willing to swear in all good faith that the two were the same person. There have necessarily been cases of mistaken identity in time past; the innocent have suffered for the guilty. No one is more unwilling that this should happen than the police authorities themselves, and now with the modern finger-print system

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[1] The term "dirty thief" is still a common one in the police force in Scotland. It signifies a low type of thief who would not hesitate to use violence on all occasions.

they can confidently say that there remains no possibility of mistaken identification. The public and the criminal may rest assured that now no error can possibly be made in identifying a former criminal.

First and foremost I would like to point out that the finger-print system is not primarily concerned with the detection of criminals by means of finger-marks accidentally left on articles which they have handled at the place of the crime; that is merely a side issue, and altogether a minor point. I remark this because I have heard it repeatedly said that the finger-print system is doomed owing to the fact that criminals may wear gloves and thus defy detection.

An amusing cartoon was shown in one London journal. It depicted a youthful burglar, impatient at the time wasted by his older and more experienced employer in putting on a pair of gloves before starting to work. The youth taunts his master with becoming a "dandy," whereupon the experienced cracksman tells the lad that when his finger-prints become as well known to the police as his own are, then the lad will take to wearing gloves also.

Let the criminal wear his gloves; he will certainly leave no tell-tale finger-marks behind him. If perchance he is seen outside a building with gloves on, the local policeman will know what he is up to. In any case the authorities at New Scotland Yard will not be alarmed for their finger-print system. The real work of the department is for the *identification* of criminals. What the authorities profess to do is to take the finger-prints of every criminal passing through their hands, and at any future time they will be able to identify that man or woman by again taking their finger-prints and comparing them with the previous records.

For instance, the Glasgow police catch a man at some mischief; it only happens to be a minor offence, but they suspect the man is not a first offender, although he is unknown to them. He says he is "John Smith," and so on, but it really makes no difference what name he chooses to select, nor how cleverly he may have disguised himself, he can easily be identified. The Glasgow police take an impression of his finger-prints, and post these to the Registrar of Habitual Criminals at New Scotland Yard. When the prisoner is brought before the magistrate, a short remand is asked so that inquiries may be made concerning the prisoner. This enables the police to have Scotland Yard's reply. The reply received may be that the prisoner is not "John Smith," but "Jeremiah Jones," who has a long list of previous convictions entered up against him. Indeed, his record is so bad, that instead of being treated lightly as a first offender he is sent to penal servitude, and rightly so, for it is quite evident that the man has no intention of trying to live an honest life. His only concern is to evade the police. It is obvious that but for this system of identification the man might have succeeded in passing himself off as "John Smith," and might soon have been once more at liberty to practise his degrading crime.

Not very long ago we were all shocked to hear of the terrible murder of a whole family of innocent people. Suspicion fell upon a man who had previously had some business transactions with the father of the family. The murder was of such an atrocious nature that it was evident that it was the work of some desperate character. The suspected person, however, was only known as a quiet-living person. His finger-prints were taken, and despite the fact that one finger could not be included in the record owing to serious inflammation, the experts had no difficulty in identifying the prisoner with a man who had previously undergone penal servitude, and who, while in prison, had made a very desperate attempt to escape. The man was ultimately proved to be the guilty person.

When the system of identification of criminals by finger-prints was introduced into Australia a few years ago, the act authorising its use was christened "The Kathleen Mavourneen Act" by the criminal class. For the immediate effect of the Act was to drive the habitual criminals out of the country. The returns for the New South Wales gaols since the introduction of this Act make most impressive reading. The number of inmates was steadily reduced, month by month, and in less than two years the total number had decreased by about one-fourth of the whole.

A large number of Australia's habitual criminals went across to New Zealand, where there was no finger-print system. There the ingenious criminal might succeed from time to time in hoodwinking the police, and when caught still pass himself off as a novice in crime. The influx of these criminals was so great that New Zealand was compelled to adopt the finger-print system.

By what means are the finger-prints recorded? Not by photography, as some have supposed, although photography does play an important part in the detection of criminals by tell-tale finger-marks. The method of recording finger-marks is really very simple. The prisoner is taken to a table upon which lies a flat metal plate covered with printer's greasy ink. First of all the prisoner's right thumb is placed on the inked plate, and the thumb is then used as a miniature garden roller. The official in charge gives the prisoner's thumb a rolling motion, so that the whole front of the thumb comes in contact with the inked plate. In this way the thumb lifts enough ink to give a good impression of its ridges upon paper. A special form is provided on which a separate space is marked off for each finger. In making the impression upon the paper the thumb is given the same rolling motion, so that a record of all the ridges upon the front of the thumb may be obtained. This is called a "rolled impression." Each finger is in turn rolled upon the inked plate and then an impression is immediately taken on the paper form. After the ten spaces have each received a rolled impression of the corresponding finger, there still remain two large spaces to be filled in. In one of these a "plain impression" is taken of the four fingers of the left hand together. A plain impression is taken by merely laying the fingers upon the inked plate and then flat upon the paper form. The four fingers of the right hand are made to give a similar plain impression in the other space. The object of these plain impressions made simultaneously is to enable the expert to see that the person taking the rolled impressions has recorded each finger in the correct space allotted to it.

The record is now complete, but the authorities place still one more safeguard against any possibility of error. If the records of several prisoners' finger-prints were being taken at one time, there might be a somewhat remote chance of the official mixing the papers before they were signed by the prisoners. To make assurance doubly sure, the prisoner signs the paper as soon as the form is complete, and beneath his signature he gives another rolled impression of his right fore-finger. This may be compared with the impression of the same finger in the record.

Imagine a collection of the finger-prints of about one hundred thousand different criminals, stored at Scotland Yard! What a search when the record of "John Smith" arrives to be identified! There is no use in relying upon a name index, for many a criminal's name is legion.

It will be apparent that the value of the finger-print system will depend entirely upon the facility with which the multitude of records may be referred to. One of the paper forms with complete finger-prints arrives from some distant town. It gives the prisoner's ten finger-prints very clearly, but the chances are that the name given is an "alias." How then is the registrar to begin a search among the thousands of records in his cabinets?

The classification of finger-prints introduced by Sir Edward Henry, the Commissioner of the London Metropolitan Police, is a most ingenious one, but as photography plays no part in this branch of the subject, we must pass it over. It may be of interest merely to note that the different patterns of ridges are divided off into separate classes, described as *whorls* (circular patterns), *loops*, *arches*, and *composites* (mixtures of the three former).

A definite numerical value is given to each whorl, according to the finger upon which it occurs, and so on. Any reader who is desirous of seriously following out the full method of classification will find the particulars clearly stated in Sir Edward Henry's textbook upon the subject of finger-print classification.

I was fortunate in seeing some records arrive at Scotland Yard for identification. One of the experts opened one of these and in an incredibly short time he put down all the values, etc., marking the form with its complete classification number. Looking at the figures, he went straight to a certain pigeon-hole in a certain row in the cabinet, and took from it a file or bundle of records. He then selected a certain sub-division, and taking this by itself he quickly ran over the handful of records in similar fashion to a banker handling bank-notes. He soon came to the particular number for which he was searching, and taking it out from the bundle, he laid it upon the table beside the record which had arrived by post for identification. There could be no doubt that the two records were identical. Ever so careful an examination could not discover any difference. It is a matter of no moment whether or not the two records bear the same name. The incoming record may be marked as that of "John Smith," but it is perfectly clear that he is one and the same individual as "Jeremiah Jones."

The police authorities who have caught the man in some distant town are then informed of the man's previous record, and he is dealt with accordingly. If Scotland Yard have the man's portrait, which very probably they have, they post this as well as the official description of the man's person. Poor "John Smith" is fairly cornered; he cannot by any possible means disguise his tell-tale finger-prints.

The absolute reliability of the finger-print system depends upon the fact that the formation of these ridge patterns is unchangeable, and persists throughout a lifetime. There will necessarily be a difference of size between infancy and old age, but the complex detail of the pattern never alters in the least. Indeed, a person may be identified after death by means of the finger-prints, if a previous record has also been taken. If Rameses II, the ancient king of Egypt at whose court Moses was brought up, had left us a record of his finger-prints, we could have identified his mummy even now.

It sometimes happens that when a prisoner knows that his finger-prints are to be taken, he will rub the points of his fingers very vigorously upon the walls or floor of his cell, till he tears the skin and causes the fingers to bleed. As a rule he only damages the tips of his fingers, which do not come in contact with the paper record. Even if a criminal removes the ridges on his fingers by means of a fine file, it only requires a little time for the ridges to reappear, and exactly the same complex design is again formed. Here is a true individuality! The prisoner's appearance may be altered as much as he chooses; time may make very marked changes in his features; the colour of his eyes may even alter; his name may change with every day of the year; all these factors make no difference whatever in the modern means of identifying the man; his finger-prints are even more unalterable than were the laws of the Medes and Persians.

The finger-print system was used in a somewhat modified form in the Indian Civil Service for many years before it was introduced into Great Britain as a means of identifying criminals. The Post Office authorities in India found many cases of personation in connection with examinations for appointments. One man would obtain the doctor's certificate, passing himself off as some other individual who meant to go up for the written examination, but feared it impossible to obtain a doctor's certificate. This was put a stop to by the introduction of a simple finger-print system.

It is quite possible that similar deceptions are practised in other countries. I know at first hand of one case where a man from a distant district got the local schoolmaster to go to the capital to pass a competitive examination in the name of the would-be applicant. Fortunately in this particular case the deception was discovered at the time of examination.

In India it was found that at the death of a pensioner some relative had often succeeded in personating the dead man, and in this way the Government had been cheated. The finger-print system soon put a stop to this deception, which neither a good recollection of faces nor photography could undertake to detect.

We have seen how the finger-print system gives a sure method of identification, which cannot be claimed for pictures of the persons made by the camera. We now pass on to the side issue—the detection of the criminal by accidental tell-tale finger-marks, and it is here that photography steps in and gives most valuable aid.

Much useful work has been and is being done in this direction, but it is obvious that its scope must be limited. If the criminal succeeds in wearing gloves during "business hours," this branch of the work will certainly be curtailed, but I should imagine that the "light-fingered gentry" would find gloves of any kind a serious handicap.

On one occasion a burglar entered a London mansion, helped himself to what articles he desired, and, presumably catching sight of the uncleared supper-table, he drank a glass of wine. On the glass the thief left two clear finger-prints, and by means of these the authorities at Scotland Yard were able to say that the thief was a certain notorious criminal.

It is quite evident that two finger-marks do not give a complete index to the place in the cabinet where this particular criminal's record will be found. The search, however, is made possible by the fact that the very nature or method of the crime suggests certain criminals to the authorities. It only remains to compare the tell-tale finger-marks left by the culprit with the recorded impressions of all probable miscreants.

To examine the faint marks upon the glass would be a rather hopeless task, but here the camera is called into play. A photograph is taken of the finger-marks. A very light powder may be dusted over the glass in such a manner that the powder will stick to the ridges and make the complex design more visible. At head-quarters this method of dusting on a powder has been abandoned, the authorities preferring to arrange the light falling upon the mark in such a manner that a good photographic impression is obtained without the artificial addition of powder.

It is wonderful how a faint image may be gradually built up into a strong one. Professor Reiss, of Lausanne University, has sent me a photograph giving a clear impression of the ridges upon the palm of a burglar's hand. The thief had touched the door of a room with the palm of his left hand, but the impression left was very slight, being, in fact, almost invisible to the eye. This faint mark was photographed, and the result was a rather weak negative. By making a second stronger negative from this one, and from this a third and a fourth, a good strong negative was finally obtained. The final photograph shows all the detail of the ridges, and it served to identify the criminal.

Another great value of photography in connection with finger-prints is that it provides a reliable method of enlarging the complex pattern to any desired size, so that the formation of every ridge in the pattern may be followed. The tell-tale finger-mark is photographed and then enlarged a thousandfold, so that not only every divergence of the ridges, but the very sweat-pores may be seen. Then the finger-print from the record of the suspected person is photographed and enlarged to exactly the same size. With these two enlargements before one there can be no possible mistake. Even a non-expert could say definitely whether or not these two photographs were identical. When the case is being submitted to a judge and jury the two photographs are marked off, as shown in the illustration facing page 160. The left-hand photograph is of an impression found upon a piece of glass, the finger-mark having been made by the burglar in entering some premises. The photograph to the right hand is a similar enlargement of an impression taken from the criminal's right fore-finger. The straight lines drawn upon the two photographs indicate identical points in both, and the Court has no difficulty in accepting this evidence, which proves the two finger-prints to have been made by the one finger.

I am indebted to the authorities at New Scotland Yard for these and the other illustrations in connection with this chapter. The photographs on the opposite page were taken in connection with the well-known Deptford "Mask" Murder; the trial of this case was reported in *The Times* (London) on the 8th of May, 1905. The first photograph shows the cash-box upon the tray of which a finger-print was found. The mark cannot be readily distinguished in the small reproduction shown here; it is seen more easily upon the original photograph. The finger-mark is on the upright face of the tray to the right-hand side. A photographic enlargement of this finger-print is shown in the left-hand lower illustration, while a similar enlargement of an inked impression taken from the prisoner's right thumb is placed alongside for the purpose of comparison. Other evidence was brought forward and the criminal was proved guilty.

In this case the tell-tale finger-print was only used to show that the prisoner had handled the cash-box, which had been found open at the scene of the murder; it was not used as a means of discovering who the culprit was.

It may be of interest to mention two other cases, of

By permission of the authorities at New Scotland Yard

FINGER-PRINT FOUND ON CASH-BOX

The left-hand lower illustration is a photographic enlargement of the finger-mark found upon a cash-box left at the scene of a noted murder. The neighbour photograph is of the prisoner's finger-print taken on paper. The general similarity is apparent. (See chap. xi.)

different types, in both of which the tell-tale finger-prints did lead directly to the detection of the criminals.

A burglar entered a house by removing a pane of glass from a basement window. On the glass taken from the window-frame were the imprints of a right fore-finger, right middle finger, left thumb, left fore-finger, and left middle finger. These were all imprinted in their natural sequence, so that the search was made a comparatively easy one. The glass was immediately taken to Scotland Yard, where it was photographed. The tell-tale finger-prints enabled the experts to look out the record which corresponded with these. There was not the slightest doubt that this criminal was the guilty person. Only a few hours elapsed after the police were informed of the burglary before the thief was located and arrested with the stolen property in his possession. He pleaded guilty; he could hardly do otherwise. No doubt he would be surprised that the police should "spot" him so very quickly as the man "wanted."

The other case to which I shall refer will show how a guilty person who is not a known criminal may be detected. A sealed packet containing bank-notes was sent through the post, and when it arrived at its destination it was found that half of the notes were missing, although the packet had no appearance of being tampered with. When the packet was examined it was found that one of the seals had been remade, and the melted wax had taken the distinct impression of a thumb. Each person through whose hands the packet had passed was asked to allow an impression of his thumbs to be taken on wax. There happened to be seven persons in all who had handled the packet. The records taken of the thumb-prints were immediately photographed and then a set of larger photographs made of these. The tell-tale finger-print upon the sealing-wax was enlarged to the same size.

A glance at the enlargements showed that five of the seven records had no resemblance whatever to the guilty mark. One of the two remaining records looked just at first something like the tell-tale impression, but on examination was seen to be quite different. The one remaining record, however, was unmistakably identical; every part of the complex pattern coincided with mathematical accuracy; the guilty person had undoubtedly been detected.

From the cases quoted we see that the tell-tale finger-prints may be left on glass, metal, paint, or sealing-wax. There are other cases in which the detection of the criminal has been possible from impressions left on paper, wood, ornaments, etc. We must not think, however, that any finger-marks or smudges are good enough for identifying the culprit; there must necessarily be a clear impression of the ridge pattern, or the finger-mark is of no use. The police might cut out a piece of lead water-pipe, upon the painted surface of which some intruder had left some dirty finger-marks, but by a preliminary examination of these with the aid of a magnifying glass it should have been apparent that there was no impression of ridges at all. The fingers had merely been drawn across the pipe, and had not been firmly pressed upon it and then lifted. It would be asking too much of any expert to read these finger-marks; there is nothing to read. Some discretion must therefore be used in determining whether or not it is worth while cutting out bits of useful property which happen to have been handled by a burglar. A simple examination through a magnifying glass will show whether or not a record of the ridges upon the fingers has been left.

There are other directions in which the camera has proved of service in detecting crime. When a man forges a signature he does not write it straight off without stopping, but does it piece by piece slowly, as though he were painting it. If such a forged signature is photographed and enlarged it shows every mark of the pen as it commences and finishes each stroke. The authorities at New Scotland Yard have made extensive use of photography in detecting forged documents in this manner.

I have also received some photographs from Professor Reiss, of Switzerland, showing how falsified documents have been detected. These photographs could not be satisfactorily reproduced by half-tone printing blocks, so I shall merely mention the facts relating to them.

In one case a document was suspected of having been tampered with, but the eye could discern no alteration. When one part of the document was photographed and an enlargement made, it was quite clear that the figures 25 had been erased from the paper.

In the second case the forger had added a tail to the letter "o" so that it was converted into a "g." No addition could be detected by the eye, but the enlarged photograph distinctly showed that this tail of the "g" was quite different from all the rest of the writing.

CHAPTER XII

PHOTOGRAPHING THE INVISIBLE

Fox Talbot and invisible rays—An ordinary portrait taken in total darkness—Photographic sensation in 1896—Curious ideas concerning the new photography—A demonstration with the fluorescent screen—Soft and hard tubes—Some experiments with a camera—Why no camera is required—Why the fluorescent screen must be used in the dark—Subjects that can be "X-rayed"—An impossible case—A visit to a large hospital—The applications in practice—An unerring witness—Further applications—Double photographs versus single ones—Risk of burning—Imitation gems.

THE title of this chapter may seem rather mysterious; I hasten to assure the reader that it has no reference to any attempt at spirit photography. I am not a believer in ghosts, excepting the old-fashioned spectre with his turnip head.

It is remarkable that we are able to photograph things which are invisible to our eyes, and yet we shall find that the idea of doing so is almost as old as photography itself.

In the earlier part of this volume I had occasion to refer repeatedly to *The Pencil of Nature*, published by Fox Talbot in 1844. This contains one very curious chapter, or part, relating to *invisible rays.* Any one who has access to a copy of *The Pencil of Nature* will find this part under the title "Scene in a Library." I made mention of this part in an earlier chapter, remarking that the scene in a library consisted of two shelves of books taken at close quarters. Talbot issued *The Pencil of Nature* in parts, giving with each portion as it was published an original photographic print. The text of each part usually had special reference to the subject of the picture accompanying it. But as there could not be much to say concerning two rows of books, from a photographic point of view, it is not surprising to find that the text of this particular part has no reference to the plate issued with it. I think it will be of general interest to give this part in Talbot's own words:—

"Among the many novel ideas which the discovery of photography has suggested, is the following rather curious experiment, or speculation. I have never tried it, indeed, nor am I aware that any one else has either tried it or proposed it, yet I think it is one which, if properly managed, must inevitably succeed.

"When a ray of solar light is refracted by a prism and thrown upon a screen, it forms there the very beautiful coloured band known by the name of the solar spectrum.

"Experimenters have found that if this spectrum is thrown upon a sheet of sensitive paper, the violet end of it produces the principal effect: and, what is truly remarkable, a similar effect is produced by certain *invisible rays* which lie beyond the violet, and beyond the limits of the spectrum, and whose existence is only revealed to us by this action which they exert.

"Now I would propose to separate these invisible rays from the rest, by suffering them to pass into an adjoining apartment through an aperture in a wall or screen of partition. This apartment would thus become filled (we must not call it *illuminated*) with invisible rays, which might be scattered in all directions by a convex lens placed behind the aperture. If there were a number of persons in the room, no one would see the other; and yet nevertheless if a *camera* were so placed as to point in the direction in which any one were standing, it would take his portrait, and reveal his actions.

"For, to use a metaphor we have already employed, the eye of the camera would see plainly where the human eye would find nothing but darkness.

"Alas! that this speculation is somewhat too refined to be introduced with effect into a modern novel or romance; for what a *dénouement* we should have, if we could suppose the secrets of the darkened chamber to be revealed by the testimony of the imprinted paper."

Thus wrote our illustrious Fox Talbot, who was not only an inventor, but a very learned man. I think the suggested arrangement will be quite clear to all. A beam of light, in an otherwise dark room, is to fall upon a prism of glass so that a spectrum is formed. This prism is to be so placed, against a dividing partition of a second dark chamber, that only the dark part of the spectrum will be opposite an aperture in the partition. The coloured bands of light are thus prevented entering the inner dark chamber. The *invisible rays* which affect a photographic plate do enter, and it is suggested that a photograph might then be taken in the ordinary way. The idea is curious; that one should sit in a totally dark room to have one's portrait taken. Talbot believed that, "if properly managed, it must inevitably succeed." I have made a search to find if any person has ever had an actual portrait taken in this way. I have been very much interested to learn that such a portrait has been taken by Mr. Edgar Senior, of the Battersea Polytechnic. A reproduction of this is shown in the illustration opposite page 196. The source of the dark rays was an arc lamp, and all the visible radiations were cut off at the lens by means of special screens invented by Professor R. W. Wood. The exposure was five minutes.

Most of us will remember the sensation caused in the opening days of 1896, when it became known that Professor Röntgen, of Wurzburg, had actually photographed the living skeleton of the hand, etc. The very weirdness of the subject fascinated us. Many people, believing that the photographs were taken by a camera in the usual way, spread fantastic ideas abroad. I remember seeing some pictures drawn by students in the University of Glasgow to represent the new photography. One picture in particular I remember; it was of four skeletons sitting in life-like attitudes around a small table, smoking, drinking, and playing cards. One even heard, at the very outset, that the photographer did not require to be in the room at all, for his apparatus would work, with perfect ease, through stone walls, and so on.

For our present purpose it does not concern us how the Röntgen rays are produced; I have dealt already with that subject in some detail in one of these Romance volumes—*The Romance of Modern Electricity*—and elsewhere. It will be sufficient to remark here that we require a battery or other source of electric current, an induction coil to increase the electric pressure, and a specially constructed vacuum tube—known as an X-ray tube. When the current is turned on, we get X-rays thrown off from a little metal target in the tube.

If we were to bring an unopened box of ordinary photographic plates within the field-of-action of the X-ray tube while at work, we should find that the plates were all fogged, just as though they had been exposed to daylight. If a photographer were asked to develop these plates, not knowing what had happened, he would say that light had got at the plates and completely spoilt them. It will be clear, therefore, that these mysterious X-rays have similar actinic or chemical properties to ordinary light; more than that, they can pass through the light-proof box containing the plates.

If one wanted to explain to some country cousin how an ordinary photograph is taken, one might get the friend to look upon the ground-glass focussing screen of the camera and see there the image of the objects to be photographed. One would then explain that, in order to take a photograph, the ground-glass screen was removed and a sensitive photographic plate placed in its stead. The image would then fall upon the chemicals on the plate and cause a chemical change to take place. When the plate is developed it will give a record of all the variety of light and shade that fell upon it.

To explain how an X-ray photograph is taken, the best plan would be to take a fluorescent screen and let the country cousin see that when the X-rays fall upon it they cause the whole screen to fluoresce or become luminous. Where is the camera? A camera is of no use with these rays; they would not be focussed by a lens,

Photo by *John Trotter, Glasgow*

AN X-RAY PHOTOGRAPH

On the middle finger there is a real diamond ring; the stones are quite transparent to the Röntgen rays. On the fore-finger is an imitation diamond ring; the stones are quite opaque to the rays. Other points of interest are explained in the text. (See chap. xii.)

and they would defy the light-proof body of the camera, passing easily through the wood and leather. In taking an ordinary photograph, we allow light to fall upon the object of which we desire to take a picture. The light is reflected by the object, passes through the lens of the camera, and falls upon the sensitive plate.

Suppose we try to photograph an object by the X-rays in the same manner as we do by ordinary light. What will happen? We let the X-rays fall upon the object; they are not reflected back to the camera; they go right through the object. What! through the human body? They do, but they meet with some resistance. The clothing offers very little resistance; the flesh is slightly more opaque to the rays, the bones more so. The rays are not reflected like rays of light, so we may dispense at once with the idea of a camera. How, then, are we going to get a photograph? We must go to the back of the object, and catch the rays there after they have passed through the body. As already suggested, we shall understand the matter better if we, in the first instance, use a fluorescent screen in place of a photographic plate.

We set the X-ray tube to work, placing it in front of us. We then let the invisible rays fall upon one of our hands; we see nothing. We then place the fluorescent screen with its coating of fine crystals between us and the hand. The screen is a simple wooden frame, upon which is stretched a piece of paper carrying on the one side the coating of crystals, and on the other side a lining of black cloth or paper. We turn the black back of the screen to the X-ray tube, place the hand right against the back of the screen, and then view the effect upon the chemicals on the front of the screen. We see that the rays are getting through the flesh of the hand with no great resistance; there is only a shading of the light at those parts. The bones, however, are much more opaque, so that we see them very distinctly as darker shadows. The rays, getting through between each finger joint, cause each joint to stand out very distinctly. We further observe that the effect is not that of a flat shadow; the bones really appear rounded. This effect is produced by the rays getting more easily through the sides of the bones than through the thicker centres. How very distinctly a ring upon the finger is seen; it is not only much blacker than the bones, but the complete circle of the ring is clearly seen. We are seeing part of the ring through the bone. Here we have a most useful property of these rays: we can see through and through.

As I have already remarked—we have almost ceased to wonder at these facts. But here comes a well-educated lady who has never happened to see an X-ray apparatus at work. We ask her to place her hand and forearm behind the screen, but she shrugs her shoulders; she would rather see some other person's skeleton. We place behind the screen, unopened, a small hand-bag, which she happens to have with her. We see that she has been shopping, for there is a small photograph frame with metal ornamentations at the corners. Behind this again we see a small case containing various sizes of scissors, etc., and in one corner of the bag is a packet of pins. At the bottom of the bag is her purse, the contents of which are clearly seen. The lady is very much amused at the idea of seeing what is in her purse, while it not only remains closed, but is further secluded inside her hand-bag.

After seeing some other person's bones, the lady is quite pleased to view her own hand and forearm. She has not quite caught the meaning of the experiment, for she is about to take her glove off, when we tell her that the X-rays laugh at trifles such as gloves. There are the buttons of the gloves, the rings on the fingers, and a wrist bangle which appears as a continuous hoop, although it encircles the arm. But what amuses our friend most is that every hook on the sleeve of her blouse is perfectly distinct, although she has a thick winter jacket on the top. There is a pin apparently in the outer jacket, and there above the wrist are some buttons of her outdoor jacket. These buttons are at the back of the arm, so that they are being seen through the bones. What a pity Charles Dickens could not have lived to see this! It will be remembered how in his *Christmas Carol* he makes old Ebenezer Scrooge see the ghost of his late partner, Jacob Marley. As Scrooge looked the phantom through and through he could see a chain of cash-boxes, keys, and padlocks, completely encircling the ghost's waist; just as we see the lady's bangle completely encircling her wrist. But listen to what Dickens says further, concerning Marley's ghost: "His body was transparent; so that Scrooge, observing him, and looking through his waistcoat, could see the two buttons on his coat behind." Little did Dickens think, when he penned these words about Marley's ghost, that they would become literally true.

If we place a cage containing a rabbit behind the screen, we can see the whole living skeleton moving about.

If we try a cage of mice or white rats, we must have a tube which will not give too penetrating rays, or we shall see through the bones and all, and only have a very faint shadow upon the screen. The chief factor in determining the penetrative power of the rays is the degree of exhaustion given to the vacuum tube. If the tube has a low vacuum, the air not having been exhausted to the greatest possible extent, then the electric current will pass more easily through the tube, but the rays produced will not be so penetrative. A tube of this description is called a *soft tube.* If, on the other hand, the tube has a high vacuum, the current has more resistance to overcome, the rays are more penetrative, and the tube is known as a *hard tube.*

I have purposely gone into some detail with the fluorescent screen, as it enables one to grasp the photographic part more easily.[1]

It would, of course, be possible to place a camera in the position from which we have been viewing the fluorescent screen, and then take a photograph of what we see upon the screen. This would not be an X-ray photograph; it would be a photograph of an X-ray screen with an image upon it. More than one experimenter did try this in the early days of X-ray work. I remember one local experimenter finding on his first negative, not only a picture of the screen with the skeleton of the hand upon it, but also an image of the front of his camera. He was attempting to focus the ordinary light

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[1] This seeing of the bones upon a fluorescent screen was really prior to the new photography. Recording the image upon a photographic plate was a later achievement by Professor Röntgen.

from the visible image on the screen, but it was evident that X-rays were also getting at his photographic plate. The fluorescent screen with its surface of chemical crystals was not stopping all the X-rays falling upon it. Some rays passed through the front of the camera, and therefore left upon the sensitive plate a shadow or shaded image of the front of the camera. This difficulty was overcome by placing a sheet of lead over the front of the camera, leaving only the lens unprotected. The light emitted by a fluorescent screen is not very bright, so that an exposure of some minutes was required. In any case a camera was only going to give a reduced size of photograph of the screen, and this is no advantage.

If we look upon the fluorescent screen as being analogous to the ground-glass focussing screen in a camera, then we at once see the simplest method of taking an X-ray photograph. Follow the method in ordinary photography; remove the focussing screen and place a photographic plate in its stead. The image will then fall upon the sensitised plate. The analogy may at first seem somewhat deficient because of the absence of the camera in X-ray work. But in ordinary photography the camera is merely a dark box in which to expose the sensitive plate to the action of light falling upon it. The camera may be a cigar box with a pinhole in it, or it may be a darkened room with a hole in the window-shutter. In X-ray work it is more usual to have a darkened room as the camera, and in this case the source of the radiations (the X-ray tube) is inside the camera. Another plan is to form a small dark chamber in which the observer can sit or stand with the fluorescent screen, while the patient to be examined and the X-ray operator with his apparatus are not in the dark at all. The patient stands against one of the walls of the darkened chamber, so that the observer can place the fluorescent screen immediately behind the part to be examined. The observer could then substitute a photographic plate for the luminous screen, and in this way take an X-ray photograph. But looking upon the darkened chamber as a camera, what purpose is it serving as far as our X-ray photograph is concerned? There is no focussing required; we merely place the photographic plate immediately behind the object to be photographed. The camera is therefore only a darkened chamber for holding the sensitive plate. A black paper envelope will therefore serve the same purpose. All we need to do in taking an X-ray photograph is to enclose the photographic plate in a light-proof envelope and place this immediately behind the part to be photographed, the object therefore coming between the X-ray tube and the plate. X-ray photography is therefore carried on in the light, the dark camera being the black envelope enclosing the plate.

It is, of course, necessary to have a darkened room when using the fluorescent screen. If one looks at the clear sky in bright daylight, one does not see the light of the stars because of the stronger sunlight. If one looks up a disused factory chimney, one then sees the stars even in bright daylight, because the eye is shielded from the direct light of the sun. In the same way one cannot see the image upon the fluorescent screen because of the brighter light in the room; the room must therefore be darkened, or the observer and screen must be enclosed in a dark chamber. This latter method is very useful when children have to be examined, for the quick hum of the induction coil and the peculiar phosphorescent light in the X-ray tube are rather alarming to a child in the dark. It is also of advantage to the electrician to be able to see his apparatus.

Referring again, for a moment, to the attempts to photograph the image upon the fluorescent screen with an ordinary camera, I recollect seeing the results of some experiments made with the cinematograph. A frog's legs were mechanically moved behind a fluorescent screen, and the cinematograph camera recorded the movements as seen upon the screen. The idea was to show the action of the joints, but the results were not encouraging, the illumination being very deficient.

Returning to the simple method of direct X-ray photography, it will be of interest to see what can and what cannot be photographed. The largest field is in photographing the bones of the human body, but many of the internal organs may also be seen and photographed, with properly adjusted apparatus.

A paralysed gentleman paid me a visit recently to ask if I could take an X-ray photograph of his head, to try and locate in what part of the brain the seat of his injury lay. He had been reading of some wonderful surgical operations made upon the brain, and he very naturally desired to know if nothing could be done in his case, which had been the result of a sunstroke. While one side of him is paralysed and the power of speech is lost, his sense of hearing remains perfect and he is as clear-headed as ever. I explained to him that while it was possible to photograph a bullet or other piece of metal lodged in the head, it was impossible to photograph the soft tissue of the brain, which is completely enveloped in the much more opaque bone. By way of illustration I pointed out that we could photograph a piece of metal enclosed in a wooden box, but that we could not photograph a piece of wood placed inside a metal box; the metal being more opaque than the wood.

What will be of most interest to the general reader is to know exactly what sort of photographs are being taken with X-rays in everyday life.

First of all let us, in imagination, visit one of our large hospitals. Here we find couches specially arranged for taking photographs of any part of the body. In one arrangement the X-ray tube is supported above the couch, so that the photographic plate must be placed beneath the patient. The photographic plate is slipped in below a parchment window, at the centre of the couch, and in this way the plate is brought close up to the patient.

Some operators prefer to have the X-ray tube beneath the couch, the tube being then supported in a little carriage or truck, which may be moved into any desired position. In this case the photographic plate is placed upon the top of the patient. The patient will lie face downwards on this couch, instead of lying upon his back, as he would do on the couch shown in the illustration.

One advantage in the couch with the tube beneath it is that the operator, having the photographic plate on the top of the patient, may lay a fluorescent screen on the top of the photographic plate, and thereby see that the tube is giving a good image. When the operator is going to use the viewing screen during the time of exposing the plate, he must not use photographic plates made of lead glass, for it is opaque to X-rays. Other glass will allow the rays to pass through the plate and cause the screen to fluoresce, and at the same time record the image on the sensitive plate.

What advantage is to be gained by watching the image on the screen while taking an X-ray photograph? The operator can see how his X-ray tube is behaving. He knows that the exposure for a certain tube should be about two minutes, but tubes sometimes vary very much during use. If the operator sees by the screen that the rays are falling off in intensity, or, on the other hand, becoming too penetrative, he can regulate the electric current accordingly. He may also lengthen or shorten the time of exposure if necessary.

What sort of photographs does the X-ray operator get? Excellent pictures of the bones of the human body, such as seen in the illustration opposite page 180. If the reader has only seen photographs of the bones, I fear that his first impression, upon seeing a collection of photographs of other parts of the body, would be that they are very poor affairs. They certainly are not much to look at from a pictorial point of view. There is an absence of the clearly defined lines seen in an X-ray photograph of the bones, for we have not the same differences of opacity. If one has expected to find an X-ray photograph of the heart to be anything akin to the illustrations of that organ, as shown in books on physiology, then one will be sorely disappointed. One only finds a dull grey and rather indefinite mass. Yet it is possible to locate an enlarged blood-vessel, known as an aneurism. This is of great importance, as the following case will testify.

A medical friend had a case sent to him in connection with the Workmen's Compensation Act of Parliament. There was a dispute as to whether or not the workman had an aneurism; the doctors differed. The X-ray photograph, however, showed clearly that no aneurism was present, and its testimony could not be disputed.

Enlargement and displacement of the heart are easily detected by the new photography; and while the photographs are not pictures, they are of much value to the medical man. Without going into surgical details, I may merely mention that cases of tubercular lungs are photographed to advantage. The surgeon may also find whether cancer has merely affected the soft tissue or has attacked the bones.

Another very important subject of X-ray photography is *stone in the kidney*. It is sometimes very difficult for surgeons to tell from the symptoms whether this trouble really is present or not. The X-ray photographer makes matters quite clear, showing how many, if any, of these bodies are present. To the ordinary person these photographs would appear at first as the result of fogged plates with some darker markings upon them. There is so little difference in the opacity of the organ itself and these aggregations of salts, that the whole photograph looks like a dull grey indefinite mass. In order to illustrate the great utility of these photographs I may mention the following case.

A medical friend, who has had a large experience in such cases, had a patient brought to him in whom the symptoms seemed very decidedly to show the presence of this trouble. My friend took several photographs, and said that there were no foreign bodies present in the kidney. The patient, however, was quite positive that stones did exist, although the X-ray photographs failed to detect them. He was so certain that he insisted upon the surgeons performing an operation. The surgeons had to carry out the patient's wishes, but on operating they found that, despite all the symptoms, there were no stones present; the X-ray photographs were confirmed as truthful witnesses. One X-ray photographer informs me that, as far as he knows, he has never yet had a case of a mistaken photograph. He has never sent a case to the surgeons saying that the trouble was present when it was not found to be so upon operation.

As already indicated, the largest field of service for X-ray photography is in connection with the human framework. Many eminent surgeons will not operate until they see a photograph of the injured bones. Not only are fractures clearly shown, but also malformation and parts affected by disease. The surgeon may also see how the fractured bones are setting. This is a great boon. It enables the surgeon to examine a troublesome fracture which he has previously set without requiring to remove the splints, etc. In cases of fractured arms, some surgeons in private practice get their patients to call and have the injured limb photographed each day while the arm is setting.

The use of X-ray photographs for detecting pieces of metal in the body has already been referred to. A child swallows a coin, and the X-ray photograph at once detects the intruder. Not only does it tell whether the coin has stuck in the gullet or passed into the stomach, but it shows the exact position in which the coin has lodged. In the case of a child swallowing a coin, it is usually sufficient for the X-ray operator to examine the patient with the fluorescent screen, and merely note down the position of the coin for the surgeon without taking a photograph. When, however, a child swallows a toy bicycle or performs some other extraordinary feat, it is of importance to be able to give the surgeon a photograph to have beside him while operating. In the case of a coin, there is no operation further than fishing the intruder out with a coin-catcher. The London Hospital did have a case of a little girl of four and a half years who swallowed a toy bicycle of considerable dimensions. With permission of the hospital authorities I used this photograph as the frontispiece to my *Electricity of To-day*. In time of war it is also of great service to the surgeon to be able to locate the exact positions of bullets in the body.

Perhaps the best known of all the uses of the X-rays is the detection of broken needles in the hands. Before the days of the new photography it was a very troublesome operation to remove these intruders. Even with good X-ray photographs it is not an easy task if the part of the needle happens to be small, and if it has only temporarily lodged in a place from which it can be easily moved along. The wanderings of a broken needle within the body are strange indeed, and it is in the locating of the needle's whereabouts that the X-rays are so useful.

X-ray photographs are taken to locate small particles of metal in the eye. By taking two photographs, with the tube in different positions, it is possible to calculate the exact depth at which the foreign body is lodged. To emphasise the importance of these double photographs, I may state one case of which I know at first hand. A workman, having got a small piece of brass into his eye, had it X-rayed in the ordinary single-photograph method, but on operating the surgeon could not find the speck shown in the photograph. Later on he had it X-rayed by the double-photograph method; the depth at which the object lay, and its exact position, were then calculated. The surgeon was able now to locate the miscreant, but unfortunately it was then too late to save the eye.

It must be clear to all that X-ray photography is of very great value to the surgeon. Even the dentist occasionally calls this new photography to his aid. He may place a small photographic film inside the mouth, and use an ordinary X-ray tube outside. In this way he can photograph the roots of teeth in the jaw.

One hears a great deal about the danger of the X-rays "burning" the flesh. There is, unfortunately, this disadvantage, but it concerns the operator very much more than the patient. The patient runs practically no risk now in the hands of a qualified operator. The man who is continually working with X-rays, however, runs considerable risk, but it is fortunate that the X-ray operators are willing to expose themselves to this risk.

This risk of "burning" is almost entirely absent from the practice of X-ray photography. It is only when very long exposures have to be made for curative purposes that there is any real risk. In these therapeutic cases every precaution is taken by using lead glass shields for the tubes, leaving only a small window for the rays to pass out by and attack the diseased part.

A medical friend showed me some special gloves which were sent to him as being proof against X-rays. When a photograph was taken, however, of the protecting glove with a hand inside, the negative showed that the glove was not opaque to the rays. The skeleton of the hand was observable upon the photographic plate, which would not have been the case had the gloves been impervious to the rays.

The surgeon may learn much by taking photographs of the different joints of normal bones. By a series of photographs of the joints in different positions, he is able to see exactly how the bones forming each joint are moved.

There are other uses to which X-ray photography may be put, such as the detection of imitation diamonds, rubies, etc. In the illustration opposite page 180 a real diamond ring will be seen on the first finger, the real stones being quite transparent, and on the middle finger is one with imitation diamonds, the stones being opaque. The difference is very marked. We might have two ruby rings, so like each other that no one but an expert could distinguish them, but an X-ray photograph would show the real rubies to be transparent, and the imitation ones of coloured glass to be opaque to the rays.

In the photograph of the lady's hand and forearm, it will be observed that the sleeve of the outdoor jacket is scarcely visible; only its fancy metal buttons have been recorded. The hooks are on the sleeve of the lady's blouse, and look rather strange without their accompanying eyes. The eyes were made of thread and so do not appear. The complete bangle encircling the wrist shows at one part through the bone of the arm. The glove buttons are seen, and what is very strange—the silk sewing upon the back of the glove. This I presume is due to the dyer having added lead to his dye in order to weight the silk.

CHAPTER XIII

MORE INVISIBLE RAYS

All light is invisible—Photography discovers ultra-violet light—A puzzled photographer—A great boon to suffering man—Photographing an invisible inscription—Ultra-violet rays versus X-rays—Photography discovers an unknown property of matter—An historical experiment—Radio-activity—Some interesting negatives—An amusing incident—Some points of interest.

IN the preceding chapter we have considered photography by means of X-rays. These are not the only invisible rays which affect a photographic plate. Some of us were taught at school that all light is invisible. Of course it is; we cannot see the ether, and therefore we cannot see any motion or vibration of it. If we could do so, we should then see light at night time far out in the universe, beyond the shadow of our earth. Light is passing out from the sun to the other planets through the dark space which we see encircling our globe at night. We do not see this light. It is only when the ether waves, called light, enter our eyes that we have the sensation which we recognise as due to light. This light may come direct from its source to our eyes, or it may fall upon some object and then be reflected to our eyes. We do not see the light itself; we may see the source of light. When we speak of invisible rays, however, we simply mean rays which do not affect our

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PHOTOGRAPHS TAKEN WITHOUT VISIBLE LIGHT

The left hand illustration is a portrait which was taken without any visible light entering the camera. The right-hand illustration is the photograph of a carved ivory needlecase taken in the dark by the invisible rays given off by radium. (See chap. xii.)

sense of vision. It will therefore be understood that while all light is invisible, we may still use the words invisible rays to describe those rays to which our eyes do not respond.

In the beginning of the preceding chapter we saw that when a beam of light was passed through a prism and then allowed to fall on a photographic plate, there was a darkening of the plate beyond the range of the visible spectrum. The photographic spectrum was much longer. It is clear that these rays outside of the visible spectrum are not what we term light, and yet they must be contained in ordinary light, for we have nothing but a beam of light passing through the prism. These invisible rays are called *ultra-violet light*, and we can easily assign them their proper position in the photographic spectrum if we remember enough of our school-day Latin to know that *ultra* means *beyond.* These rays are beyond the violet end of the spectrum.

It is only natural to ask if there are any invisible rays at the other end of the spectrum below the red. The photographic plate would seem to answer in the negative. Indeed, an ordinary photographic plate will not be affected by any part of the spectrum below green. It was this fact which suggested to photographers that they might carry on their developing processes with the aid of a red or orange light, instead of working away in total darkness as they had previously done.

We have already seen that special photographic plates can be made which are sensitive to all colours, otherwise colour photography would be impossible. That is to say, we could not get a black and white record of red and yellow colours unless the photographic plate were sensitive to these rays. If an addition of an aniline dye, a product of coal tar, is made to the chemical composition on a photographic plate, it becomes not only sensitive to all the visible spectrum, but it reveals invisible rays below the red. These invisible rays are called *infra-red*, signifying that when a beam of light is analysed these rays are found below the red end of the spectrum. The photographic spectrum therefore stretches out beyond both ends of the visible spectrum, and measures about eight times the length of the visible spectrum.

These infra-red rays will, of course, take no part in ordinary photography, while the ultra-violet rays will do so. The ordinary photographer may be quite unaware of the presence of these ultra-violet rays. I remember, however, an occasion when these rays played a trick upon a friend. He was photographing a black and white drawing made by an artist, but when reproduced the whites of the drawing came up impure; they looked more like grey. At first my friend was somewhat puzzled, but it occurred to him that the artist must have happened to use some white paint which absorbed ultra-violet light. The photographer was using an arc lamp to light up the picture, and though this light is rich in ultra-violet light, the white paint did not reflect these rays back to the plate, while a piece of white paper would do so. The consequence was that the whites appeared dirty in the reproduction. Had the photographer asked the artist to paint the picture again with another white paint, the artist would possibly have thought the request to be an absurd one, for the white looked as white as it could be made.

So it was to the human eye, but we are not conscious of the presence of ultra-violet light; it does not affect the eye. The photographic plate is more sensitive in that respect, and records the presence or absence of these rays.

The photographer in this case did not require to ask that the painting should be repainted. He adopted an ingenious plan. He photographed the picture through a transparent liquid which absorbed all the ultra-violet light. This meant that no ultra-violet rays were allowed to enter the camera at all. It was therefore of no moment whether the white paint was reflecting ultra-violet rays or not. In this way a perfect copy of the picture was made.

The photographic action of the ultra-violet rays was known in the very earliest days of photography, and, indeed, the discovery of the existence of these rays was due to their photographic action. It is these ultra-violet rays which have enabled us to fight that distressing disease known as *lupus*, for it is these rays which are produced in abundance by the Finsen lamp. Photography may therefore claim the discovery of these beneficial rays, which have proved victorious in many cases quite incurable by other means.

It will be evident that it was these rays of ultra-violet light which produced the portrait taken in total darkness, which was mentioned in the preceding chapter.

In one of the Christmas lectures delivered at the Royal Institution of Great Britain in 1896, Professor Sylvanus Thompson made an interesting experiment which demonstrated the photographic action of these ultra-violet rays. On a board there was a large sheet of apparently plain white paper. When the light of a powerful arc lamp was thrown upon the paper one could see nothing but an absolutely plain white paper. A photographer then set up his camera and took a photograph of the paper. The plate was immediately developed, whereupon it was seen that there was a bold inscription upon the apparently blank paper. This inscription was quite invisible to the human eye, but not to the eye of the camera. The ordinary white light from the arc lamp was reflected by all parts of the white paper, and the eye therefore saw a plain sheet of white paper. The inscription, however, had been painted on in a colourless chemical liquid which absorbed the violet rays. This made no difference to the human eye, because these rays do not affect it in any case; the eye therefore does not miss them. The photographic plate misses these rays; if they are absent, then the photographic action is not so great. Hence when the letters of the inscription failed to reflect these ultra-violet rays to the photographic plate, there would appear upon the plate a considerable want of chemical action at these places. In this way a record of the invisible inscription is obtained upon the photographic plate.

The colourless liquid used for the foregoing experiment was sulphate of quinine dissolved in a solution of citric acid. The source of light was an electric arc lamp, which is very rich in ultra-violet light.

The illustrations facing page 206, of the blood-stained handkerchief and the faded signature, may be explained in the same way.

So far we have been dealing, in this chapter, with the invisible rays of ordinary light. A beam of white light contains not only those different rates of ether vibration which produce the spectrum colours, but it also contains these invisible ultra-violet rays. While these rays, like the X-rays, affect a photographic plate, the properties of the two kinds of rays are different in several respects. We may demonstrate the most important difference by a simple experiment. We place the hand upon a photographic plate and expose it to the action of ultra-violet rays. We merely obtain a uniform black shadow of the hand. Compare this with an X-ray photograph of the hand, and there is no comparison between the two results. The ultra-violet photograph is just the same as we could get by ordinary light if we laid some opaque object upon a negative during the exposure; the X-ray photograph I need not describe again. The ultra-violet rays will cause a fluorescent screen to shine, but only a solid shadow can be produced by the hand. The special photographic value of the X-rays lies in their penetrative power, and in the fact that different substances offer different resistances.

When Professor Röntgen made the important discovery that the X-rays affected a photographic plate, several experimenters set to work to find out if these rays, or other similar rays, could not be found in nature. Several scientific men turned their attention to phosphorescent substances; there is a phosphorescent effect in an X-ray tube when at work. A phosphorescent substance is one which, after being exposed to ordinary light, will become luminous in the dark. The phosphorescent effect is, in some cases, merely momentary; in other substances it lasts for many hours, or even for several days. Many of us have recollections of luminous match-boxes, etc., which were a marvel to our youthful minds. In the preceding chapter I had occasion to speak of *fluorescent* screens in connection with X-ray work. These screens only became luminous when the X-rays fell upon them; the effect disappeared with the withdrawal of the rays. The difference between *fluorescence* and *phosphorescence* will therefore be quite obvious.

Experiments were made to see if phosphorescent substances did not give off invisible rays along with the luminous rays. Of the different experiments, the most important was that of Professor Becquerel, of Paris. The salts of uranium were considered to be phosphorescent, although the resulting luminous effect was very short-lived. In order to find out if this substance might not possibly be giving off invisible rays, Becquerel exposed a piece of uranium salt to strong sunlight, allowing it to rest on the top of a light-proof envelope, which enclosed a photographic plate. When the plate was developed, there was no trace of sunlight, for the envelope was absolutely opaque to light; but rays had reached the plate from the uranium salts, and had formed the shadow of a metal cross, which had been laid beneath the uranium. It was quite certain that no luminous rays from the uranium had penetrated the envelope, so that the photographic action must have been the result of invisible rays emitted by the uranium salts.

Then there comes a romantic incident, which reminds one of Daguerre's magic cupboard, of which we read in an earlier chapter. It so happened that on one occasion, when Becquerel was about to expose a piece of uranium salt to sunlight, with the object of making further photographic experiments, the sun disappeared behind the clouds. Becquerel put the uranium and the enclosed photographic plate in a drawer, intending to try the experiment later. We are then informed that Becquerel coming one day and finding the uranium lying upon the envelope containing the photographic plate, the metal cross being again between the uranium and the plate, he somehow or other took the plate and developed it without subjecting the uranium to any exposure of light. He was very much surprised to find that the image of the cross again appeared upon this negative, even although the uranium had not been rendered phosphorescent by exposure to light.

I have sometimes wondered if the thought of Daguerre's magic cupboard came into Becquerel's mind, when he opened the drawer and remembered his postponed experiment. He certainly had no reason to expect that an image would be formed upon the plate, seeing he had not exposed the uranium to sunlight. Be that as it may, this photographic plate has become of historical interest. It disclosed to Professor Becquerel the fact that the uranium was giving off these invisible rays without having had an opportunity of bottling up the sunlight.

Could it not be that the uranium had still retained some of the sunlight effect from a previous exposure? This was not likely, as the phosphorescent effect of uranium is of very short duration. To make assurance doubly sure, Becquerel took some uranium salts which he had chemically combined and crystallised in the dark. There could be no question of sunlight with these salts, as they had never seen the light. He then experimented with this virgin substance upon a photographic plate, and he found that there were invisible rays given off, just as energetic in their photographic action as were the rays of the earlier specimens which had been carefully exposed to sunlight. This was man's first knowledge of *radio-active* bodies, and in honour of the discoverer these rays have been named *Becquerel rays.*

It may seem to the reader as though this discovery was not of very much consequence in the workaday world. We cannot tell how far-reaching it may be. It led to Professor and Madame Curie's discovery of radium. But what I want to point out at present is that *photography* was the means by which Professor Becquerel made this historical discovery of bodies emitting invisible radiations. Herein lay the discovery of a new property of matter—a property, the existence of which had remained sealed in nature's book from all time, until revealed in 1896 by Becquerel's photographic plate.

It is not within the province of our present subject to trace how the Curies, following up this pioneer experiment, discovered the much more radio-active substance which they christened *radium.* An electrical test was found which proved much more sensitive in detecting a radio-active substance than the photographic plate. Nevertheless, it was the photographic plate which opened the door to this world of radio-activity.

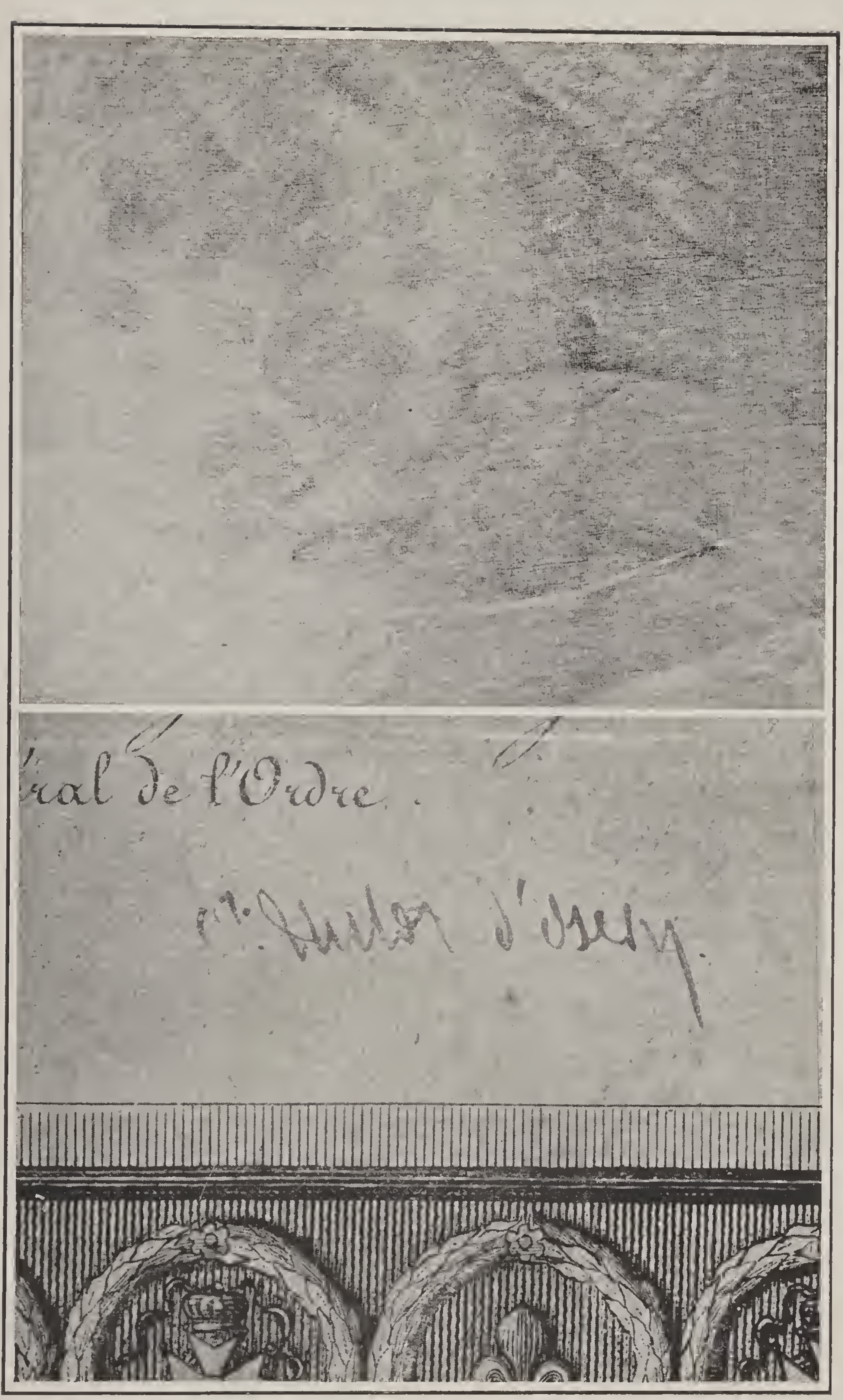
I remember seeing some of the negatives which had been exposed to uranium in order to produce various skiagraphs. The reader would not reckon them of much value, merely judging them by their appearance. They will remain, however, of historic interest. The skiagraphs or radiographs produced by radium are more distinct, but they too fall far short of those produced by Röntgen's rays. Some interesting negatives have been obtained with radium, showing metal coins, keys, sleeve-links, etc. One experimenter, Soddy, adopted a very interesting plan. He placed some radium salts in a small test tube, and using it as a pencil, he traced the letters Ra, in imaginary writing, upon the black envelope enclosing a photographic plate. When the plate was developed the letters were clearly seen upon the negative. This experiment showed how very quickly the rays affected the photographic plate.

The illustration facing page 196 is by far the best radium photograph I have yet seen. I am indebted to Mr. Edgar Senior, of the Battersea Polytechnic, for this interesting example. This experimenter has surprised photographers from time to time by his beautiful experiments. The method of taking this photograph was as follows. The object, a carved ivory needle-case, was placed in contact with a photographic plate, and a *screen* coated with a substance containing the radium was placed over it; the whole being contained in a box was kept in the dark. Although no visible radiation proceeded from the screen, the photograph was obtained on allowing some time to elapse before withdrawing the plate.

It is a curious fact that luminous or phosphorescent paints, although losing their luminous effect after several days at the most when withdrawn from exposure to light, will continue for many weeks to emit invisible rays which affect a photographic plate.

The well-known incandescent gas mantle emits invisible rays. An unused mantle is cut up so that it will lie flat upon a black envelope containing a photographic plate. The plate and the mantle are then put aside in a dark drawer for eight days, and when developed it will be found that these invisible rays have photographed the texture of the mantle upon the negative.

Many ordinary substances will similarly affect a photographic plate, if the exposure be long enough; an exposure of several days may be required. A piece of polished zinc is a very active body, while the printer's ink upon a five-pound note will photograph itself upon a photographic plate in the dark. I remember an amusing incident in this connection. Many years ago a friend received a boxful of photographic plates to develop for a friend of his. When the plates were developed, not only did some excellent photographs of interesting places appear, but an uninvited guest had also been at work. Across each picture there was a bold inscription printed. In the clear sky of one picture appeared the words "use so-and-so's baking powder," while on another stood an advertisement of soap, and so on. In packing up the plates, the sender had placed pieces of printed paper between them, and on the journey the printer's ink had affected the still sensitive plates. These substances are not radio-active bodies; they will not respond to the electric test of altering the conductivity of air. Some physicists maintain that these



By permission of *Professor Reiss, Lausanne University*

PHOTOGRAPHING THE INVISIBLE

The upper illustration is a photograph of a portion of a handkerchief from which some blood-stains had been washed out with soap and water, so that they were quite invisible to the eye. The photograph reveals their presence. The lower illustration is a photograph of part of an old French document from which the signature had disappeared. The camera saw what the eye could not see. (See chap. xiii.)

bodies emit invisible rays which act upon the chemicals on a photographic plate, but others believe the action to be a purely chemical one.

It was thought by some experimenters that glow-flies or fire-flies emitted invisible photographic rays which could penetrate a sheet of iron and then affect a photographic plate. One experimenter in Japan was said to have proved this by shutting up one thousand fire-flies in a shallow box, and then exposing a photographic plate beneath a sheet of iron upon which the box rested. I am informed, however, that this statement was afterwards withdrawn; possibly some stray light affected the experimental plate.

Referring again, for a moment, to radio-active bodies, there is one other point which may be of interest to the reader. He may wonder if it is possible to make a body radio-active, or if it is only a natural property. We shall take a case in which the photographic plate gives us a reply. If an aluminium or copper wire be electrically charged, to a high negative potential, for some hours, it is found that the wire will affect a photographic plate, and that it retains this property for several hours after the charge has been withdrawn. It has been proved, in this case, that the surface of the wire becomes radio-active, because radio-active matter from the atmosphere has been deposited upon it. It is not possible to make a body radio-active, except in this sense.

It does not concern us in our present subject to inquire how radio-activity has brought to man the new knowledge of the disintegration of the atom. The chief point of interest for us at present is the way in which this new knowledge originated. We see Becquerel examining a newly developed photographic plate, and finding upon it the faint shadow of a copper cross, which he had laid in the dark, between a piece of uranium and the black envelope enclosing the sensitive plate. Here, indeed, began a true romance in the world of science.

CHAPTER XIV

PHOTOGRAPHING MICROBES, &c.

Daguerreotypes through the microscope—How photographs are taken through the microscope—An invisible image—Photographing a spider's foot—Some beautiful microscopic shells—Nothing left to the imagination—Interesting points in high magnification—A difficulty overcome — Microbes — What are bacteria? — Photomicrographs of metals.

IN X-ray photography we have seen how it is possible to photograph things which are invisible to the eye, because they are enclosed within other substances which are opaque to light. In the present chapter we are going to consider the means of photographing bodies which are invisible to the eye because of their minute size. While these objects are far below the range of our vision, we can see them by means of powerful microscopes. And it is because we are able to photograph objects through the microscope that we can obtain pictures of things that are below our range of vision.

The idea of photographing through a microscope is not new. In the days of the daguerreotype a few scientists took photographs through the microscope, but the really fine work of photo-micrography has all been done during the present generation.

We may gain a great deal of interesting and useful knowledge by means of these photo-micrographs. One occasionally hears these pictures spoken of as microphotographs, but that is an error. A micro-photograph is a very small photograph, such as we have seen in souvenir penholders. When these are viewed through a small magnifying glass fixed immediately in front of the photograph, one sees quite a good picture of some place of interest.

A glance at the illustration on the opposite page will show the beautiful detail obtained in a photograph taken through a microscope.

When one takes a photo-micrograph one merely uses the microscope as the lens of the camera. The camera is only a dark chamber in which to place the photographic plate in the proper position to receive the image formed by the lenses of the microscope. In other words, we wish to take a photographic record of the image we see when looking through the microscope.

When we speak of photographing a spider's foot, a fly's wing, and so on, it is not to be supposed by the novice that we merely catch a spider or a fly and place it under the microscope and camera. We must first of all mount the object carefully upon a microscopic slide, so that it is firmly fixed between the glass slide and a thin cover glass. This we do in order that we may get the object flat enough to be focussed. Even then we shall find that the thicker parts of a fly's wing are somewhat out of focus when the flat surface of the wing is in perfect focus.

Sometimes we find the microscopist taking photographs with a very long camera, or with several cameras coupled together, measuring many feet in length. This he does in order to get a large picture giving detail which could not

Photo by *Arthur E. Smith, London*

A SPIDER'S FOOT

This photograph was taken through a microscope, as explained in the text. It is difficult to realize that all this detail is contained in the foot of such a tiny creature as a spider. (See chap. xiv.)

be properly seen in a smaller photograph. Some friends maintain that one can get as good results by simply enlarging a smaller photograph, but with many microscopic objects this is not the case.

I have had many an argument with microscopists upon this question. I hold that it is unfair only to measure the object in the final photograph, which may happen to be an enlarged copy of a very low magnification, and state the actual number of diameters that it is greater than the original object. One ought to state that the picture is an enlargement of a certain magnification. If we turn to the photographs shown opposite page 284 we have there a clear proof that an enlargement of the smaller abbey would not have all the detail shown in the telephotograph below. It is hardly fair to make a comparison between the reproductions in the book, as the graining of the process screen might destroy some fine details in the smaller picture; but taking the original photographs I have examined them very carefully, using a powerful magnifying glass to the smaller picture, and there is a lot of detail in the larger photograph which does not exist in the smaller picture. To take one item only, one can see telegraph poles and wires to the left of the abbey in the tele-photograph, but there is not the faintest impression of these in the smaller image. No amount of enlargement would ever add these to the image of the smaller photograph. Hence my argument concerning the microscope holds good.

The photo-micrographer has really two focussings to attend to. He first of all adjusts the focus of his microscope till he gets the image perfectly sharp. To do this he removes the camera and focuses his microscope in the ordinary way. He then couples his camera to the microscope and focuses the image upon the glass screen of his camera.

If one thinks of an ordinary spider with his long thin legs of seemingly simple construction, one does not expect to see much detail in the foot of so small a creature. Its foot is about the size of the dot at the end of this sentence, and if one had never used the microscope one would probably think that the spider's foot was in the form of a single round dot. The illustration, facing page 210, shows how much detail is really contained in so small a space. There is no artist's imagination to be allowed for here; the spider's foot was simply mounted between two pieces of glass and then photographed through a microscope. The spider's foot in the original photograph was 400 times longer and 400 times broader than the real object. The block-maker, however, has had to reduce the photograph from 10 inches by 8 inches to 4½ inches by 3½ inches in order to suit the page of this book.

After examining the photograph of the spider's foot we can better understand how the little creature is able to suspend herself on her almost invisible thread. The late Dr. Carpenter tells us that the spider uses these comb-like claws for cleansing purposes, and for the manipulation of the thread of her snare. The same lover of nature tells us that these little claws are so sensitive that "by resting them upon a trap-line of silk carried to her den, she can, by a veritable telegraphy, discover instantly, not only the fact that there is prey upon her snare, but the exact spot in the web of the snare in which that prey is entangled." This she can do when she is "far beyond the reach of vision."

We pick up another microscopic slide, marked *polycystina*, and we desire to take a photograph of this through the microscope. Nothing can be seen by ordinary vision except a number of very small specks below the cover-glass. These might be mistaken for dust or fine white sand. In the lower illustration opposite page 216 we see one of these slides of polycystina photographed full size. What a difference between the visible detail in this and that in the larger illustration above it! This large photo-micrograph only represents a very small fraction of the polycystina contained in the microscope slide shown beneath. We no longer see simple specks of matter. Each of the tiny specks is found to be a beautifully formed shell. And what is even more marvellous, each of these tiny fossil shells at one time contained a living creature. It seems almost incredible that so much design can possibly be contained in so small a speck in nature.

These polycystina are fossil shells, the homes of creatures which lived many ages ago. Do any of these tiny creatures still live upon the earth? Yes! we find their living representatives near the surface of certain oceans, and they are named *radiolaria*, having little rays projecting from their shells. When these tiny creatures die their shells fall to the bottom of the ocean, and after long ages go to form hard rock. It is in these rocks that we now find the polycystina of radiolaria which lived long ages ago.

Photo-micrography provides us with a means of spreading knowledge concerning microscopic objects much better than can be done by direct microscopy itself. Every one is not the possessor of a microscope, but although one may never have looked through a microscope, one can understand a photo-micrograph. When an ordinary person knows that he is looking at an actual photograph, he feels confident that he is seeing nature really as she is. When we came across wood engravings of snow crystals in our school books, many of us, I doubt not, gave the artist credit for a rather lively imagination. These exquisite and intricate geometrical designs, labelled snow crystals, had doubtless been suggested to the artist by the snowflake. We too had sometimes seen wonderful configurations in the flames as we sat listlessly over the fire. When, however, we are shown an actual photo-micrograph of the crystals formed by breathing upon a window during frost, we feel we are on safe ground. We know that all that multitude of exquisite forms must really exist exactly as we see it in the photograph. I do not mean to suggest that the artist wilfully misrepresents a microscopical object; I am describing the possible appreciation of such drawing in young minds. In the case of photo-micrography there can be no personal equation to discount—no artist's imaginative licence to allow for.

Then, again, not only does photo-micrography ensure a faithful reproduction, but the artist Light will draw the most delicate lines and complex structures in a manner which the draughtsman's pen could not accomplish. Again, what the skilled draughtsman would take laborious hours and perhaps days to draw, the pencil of nature will draw in a few seconds if the magnification be low, or in a few minutes if the magnification be great. Allowing for the time required to arrange the camera, to develop the negative, and to print the paper photograph, the whole time is a mere fraction of the draughtsman's time. Besides all this, the man who cannot draw a straight line or shape a curve may produce an excellent picture of the most complex organism by means of photo-micrography.

There is an interesting point that arises in connection with high magnifications. We all know the meaning of the refraction of light; we have seen a stick placed at an angle in water, and we have noticed that the stick appeared to be very decidedly bent at the point where it entered the water. We are therefore aware that light is bent or refracted when passing from one substance to another, such as air and water. The same happens when light passes from glass to air, and so we may picture the rays of light being bent as they pass out through the cover-glass of a microscope slide into the air space between the slide and the lens of the microscope. Even although the cover-glass is made as thin as it is possible, some rays will be bent outwards so that they miss the small lens altogether, and therefore fail to enter the microscope. This means that the resulting image will not be so bright or so perfect as it would otherwise be. How can this difficulty be overcome? We certainly cannot hope to make a thinner cover-glass; already it is merely a wafer, the weight of which is hardly perceptible in the hand. We can, however, prevent the bending of the rays of light if we supply the light with a uniform path. The bending is caused by the difference in density between the glass and the air. If we fill the intervening air space, between the microscope slide and the lens, with water or with cedar oil, then the light will have no change of density to pass through. It will suffer no refraction in passing from the glass to the water or oil, so that all the light will enter the microscope and produce a brighter image and a better photo-micrograph. When one sees in a price list of microscopes, *water-immersion* or *oil-immersion* lenses, the meaning will be quite clear.

In our first illustration (p. 210) we have a demonstration of how photo-micrography is of assistance in the study of insect life. Then in the illustration facing page 216 we have an example of how the beauty of very minute organisms is revealed. We might add photograph after photograph, showing a whole world of marvels beyond the range of ordinary vision.

There is one other field of photo-micrography with which I shall deal at some length, because it is doubtless the most marvellous of all, not from the artistic, but from the practical point of view. I refer to the photography of microbes. In the two illustrations, just referred to, we have photographs of very minute objects, which are not themselves invisible, although the beauty of their design is hidden until revealed by the microscope. In the present case we are going to deal with photographs of objects which are totally invisible to our eyes; far below the range of unaided vision.

It is a natural question to ask what these microbes or bacteria really are. I have occasionally found people

Photo by *Arthur E. Smith, London*

PHOTOMICROGRAPH

The large illustration is a photograph, taken through a microscope, and shows a very small portion of the "white specks" (polycystina) seen in the lower illustration, but magnified enormously. The lower photograph gives the actual size of the objects which were photographed by the microscope. (See chapter xiv.)

picturing microbes as some kind of very minute insects, so small, of course, that they cannot be seen, but yet endowed with a sort of instinct or volition, enabling them to leave one infected person and direct their attack against a second person who happened to offer some attraction or predisposition. A glance at the photographs of microbes facing page 220 will dispel any stray idea of insect life.

Scientists were not very sure at first what bacteria really were. It could not be decided whether these minute organisms belonged to the animal or the vegetable kingdom. Were they a low form of animal life, or were they simple vegetable life? There was a great deal of lively debate before these all-important little organisms were finally settled down in the domain of botany. What then is a microbe or bacterium? It is a very minute vegetable organism; a microscopic fungus, classed along with moulds and yeast. The study of bacteriology has been of the very greatest benefit to mankind, and photomicrography has played no small part in the advancement of this knowledge.

It is not within our present province to describe how the bacteriologist cultivates bacteria in peptonised meat jelly, etc., for the purposes of examination. Nor, again, how he stains his specimens with aniline dyes to make the forms of the bacteria more visible. It will be of interest to the reader, however, to see exactly what some of those bacteria look like. I have selected four different kinds of bacteria which will be quite distinct from one another to the eye of the uninitiated, and at the same time will represent well-known diseases.

Looking at the illustrations (p. 220), we notice that in the lower right-hand photo-micrograph some of the bacteria have the appearance of drumsticks. This peculiar formation is found in the disease germ of *lockjaw*, or to give it its more scientific name, *tetanus*. When the bacteria are in the form of little straight rods, as shown in this illustration, they are called *bacilli*, the singular of which is *bacillus*. It is only at a certain stage in its life-history that the tetanus bacillus has this drumstick appearance.

As this photograph is magnified one thousand diameters, the real bacillus is only one-millionth of the area shown here. If these tiny organisms enter a surgical wound, they set up a series of changes in the tissue, and produce a virulent poison, which acts upon the nervous system, and causes those most distressing spasms and convulsions associated with lockjaw.

The upper left-hand photograph shows the bacillus of diphtheria. The little rods are slightly curved, and they are much smaller than the tetanus bacillus. These bacilli of diphtheria may be seen congregated in clumps, or in pairs, or they may be single. It is to counteract these tiny organisms that the anti-toxin serum is injected.

Our next photograph is of Asiatic cholera, and here the bacilli take the form of spiral threads. Sometimes one finds a complete letter *S*. To show how easily these minute disease germs may be carried from one place to another, I may refer to an epidemic which occurred in 1892. At this date a severe epidemic of Asiatic cholera originated in India, and quickly spread throughout Afghanistan, to Russia in Asia, and westwards along the route of the railway; this whole area being affected within the space of three weeks. Russian emigrants then carried the germs to Hamburg and Antwerp.

Our last photograph is of special interest, and I am indebted to Dr. R. M. Buchanan, Bacteriologist to the City of Glasgow, for the trouble he has taken in securing a photograph suitable for reproducing here. The microbe here is of an oval or kidney shape. It belongs to a large class of microbes that are more or less round-shaped and called *cocci*. Each cell is called a *coccus*. This photograph is of the micro-organism of cerebro-spinal fever, more commonly called "spotted fever." The characteristic arrangement in pairs is well shown. The large group in the centre of the photograph is contained within a cell the outline and nucleus of which are scarcely visible. The larger bodies are blood corpuscles.

All these photographs are made on the same scale. The magnification in the original photographs is one thousand diameters, but this has been reduced in reproduction, in order to get the four photographs on to the one page.

The bacteriologist is not only familiar with the shapes and forms of the different bacteria, he knows their actual measurements. The inch is, of course, much too large a unit to use, and so he takes as his unit the one twenty-five thousandth part of an inch. The cholera bacillus measures from one to two of these units in length, and about half a unit in thickness. While these figures will not convey much to the mind of the reader, they give the bacteriologist a real measurement by which he may compare the different bacteria. It is impossible for the mind adequately to conceive the actual size of any bacterium. We cannot imagine the divisions of an inch marked off into twenty-five thousand equal parts; even when divided into sixty-four parts each division looks very small. Of course, the bacteriologist is not really measuring with so fine a scale, for he does not measure the actual bacillus, but a very large magnified image of it. For instance, if his photo-micrograph is one thousand magnifications, and he finds that a bacillus in this photograph measures one twenty-fifth of an inch, then he knows that the bacillus is one thousand times smaller than its photograph, which means that it will only measure one twenty-five thousandth part of an inch in nature.

The orthodox plan of stating the amount of magnification shown in a photograph is to say that it is fifty diameters or one thousand diameters. Some people, not accustomed to microscopy, express surprise when they are informed that a certain object in a photo-micrograph is only multiplied by fifty diameters; they would have guessed a far greater magnification. It must not be thought that an object increased by fifty diameters means that it is only fifty times as large as the original. It is fifty times as long and also fifty times as broad, so that it is really two thousand five hundred times larger ($50 \times 50 = 2500$). An object magnified one thousand diameters is therefore one million times larger, and so on. It is much more convenient to state the number of diameters by which an object has been magnified. We adopt this plan in everyday conversation concerning common objects. We say that one object is twice as long or twice as broad as

DIPHTHERIA. ASIATIC CHOLERA.

SPOTTED FEVER. LOCKJAW.

By permission *Dr. R. M. Buchanan, Bacteriologist*

PHOTOGRAPHS OF MICROBES

These four photomicrographs show different types of bacteria. These minute organisms are far below the range of vision; they have been photographed through a powerful microscope. (See chap. xiv.)

another, without stopping to consider the increase in area.

Sufficient has been said to show that, in this department, photo-micrography reveals a whole world of activity, existing in air, earth, and water, which must have remained unexplored but for the microscope. It is difficult to realise that these bacteria are so very intimately connected with us as they really are; they are in the food we eat, the air we breathe, and the clothes we wear. They are in our mouths and in our stomachs. We must not look upon all bacteria as our enemies; they occupy a very important place in nature. They have very aptly been called *the scavengers of nature*, for they break down dead animal and vegetable matter. They complete the cycle of life, the dead matter being transformed into substances which again go to build up the living.

Referring to the bacteria known as disease germs, it is a natural thing to wonder what useful purpose these serve in our bodies. None whatever; they are harmful parasites; they are not fulfilling their proper sphere in nature. Just as dirt is simply matter in the wrong place, so disease is bacteria in the wrong place.

We owe a debt of gratitude to the bacteriologists who have discovered and studied these minute fungi, and who have thereby given the medical world new weapons with which to battle against disease. The bacteriologists are still at work in their laboratories, not only determining the nature of diseases, but on the look-out for further knowledge.

Many beautiful photo-micrographs have recently been taken of metals, showing their forms of construction and crystallisation, but these are of more technical than general interest. The other branches of study taken up in this chapter will be sufficient to demonstrate the very wide field which has been opened up to the scientist by the application of photo-micrography.

CHAPTER XV

PHOTOGRAPHING UNDER DIFFICULTIES

Taking photographs in a coal mine—An eighteen-inch coal seam—Some experiments with flash-powder—The photographer baffled—Plenty of light — A more disappointing expedition — A third attempt — Another defeat — A new line of attack — A long exposure — Ultimate success—The patient miners — A unique photograph.

WHEN one meets with totally new conditions in taking a photograph one feels puzzled to know how to act, what exposure to give. This was my position when I determined to go down a coal mine and try to photograph an electric coal-cutter in a very narrow seam, measuring only eighteen inches from floor to roof. Many photographs had been taken previously in coal mines, but in such cases the photographer had a reasonable space to work in. My ambition was to photograph the coal-cutting machine, and the two miners controlling it, in their exact working positions. This I wanted as an illustration for *The Romance of Modern Electricity*.

Inquiries as to the source of light to use were not very encouraging; photographers' opinions were so widely different. However, I determined to try a powerful flash-powder, believing that I could not have too much light, when the whole surroundings were to be a dead black.

I was fortunate in falling in with the manager of one of the largest concerns for manufacturing flash-powders. This gentleman supplied me with a very neat little invention of his own, whereby the powder might be ignited without the risk of having one's fingers burnt. This consisted of a small metal tray or saucer, supported upon an upright pillar passing through its centre. The tray could be slid up or down upon this pillar, and fixed in any desired position by means of a binding screw. The top of the pillar was made tubular, the hole being made just large enough to hold a wax match when folded in two. The method of igniting the powder was very simple. A wax match was doubled so that the plain end extended up above the match head. The plain end was then frayed out so that it could be easily ignited, without setting the head alight.

The prepared match was first placed in the top of the pillar, and the desired amount of flash-powder placed in the tray. The powder was then heaped up, so that it just covered the head of the match, and left the plain end projecting upwards. A light was then applied to this frayed end of the match; there was no fear of igniting the powder in this operation, as this powder could not be ignited by a naked light. When the buried head of the match, however, caught fire, its miniature explosion ignited the powder, and there was a sudden flash of very brilliant light.

Having obtained permission to make photographic experiments in a large colliery where naked lights could be used with safety, I next secured the assistance of a friend who is an expert amateur photographer.

It was necessary to carry out the photographic expedition during the night, as the coal-cutters were not at work in the daytime.

We set out by rail to the mining district, hopeful of securing an interesting photograph. The manager of the mine was very interested in our proposed experiments. He told us incidentally that several photographers had already tried the same subject, but had got no results. This was not very encouraging, yet we were hopeful that we were armed with a better source of light than our predecessors.

The manager was very good in accompanying us down the pit. I had been down several pits on former occasions, but my friend had not been previously down a mine shaft, so he got instructions to take a firm hold on the cross-bar of the cage in which we were to be lowered into the bowels of the earth. It seemed quite a long downward journey, but we had still a long way to walk after reaching the bottom. At first we walked quite erect, but on turning off the main road we were forced to walk in a very crooked position, or we ran the risk of collision between our heads and the rugged roof. When we encountered a fall of the roof, which here and there almost blocked our way, we found the photographic apparatus an awkward burden. Sometimes one had practically to crawl through a hole. At last we entered a very small road or passage, in which the roof was so low that one even knocked one's back against it when walking along with the body bent in the form of a right angle.

It was a genuine relief when the manager informed us that we had reached the end of our journey. We sat down to try and straighten out our bent backs.

This little narrow, low-roofed passage in which we were now sitting seemed to come to a dead end. The manager, however, was able to show us with the aid of his lamp that a very shallow passage ran past the end of our road. The roof close overhead dipped right down in front of us to within eighteen inches of the ground, and at this point we tapped the shallow passage. It was only a few feet in width, but it extended several hundred feet in length, while it was only eighteen inches from floor to roof. It was practically like a great big crack in the solid earth, and yet two miners were to work all night in this confined space and look after a powerful coal-cutting machine.

As the machine practically filled up the whole space from floor to roof, our only chance of photographing it would be as it passed the end of our road. I crawled into the eighteen-inch seam a little way, till I could hear the hum of the coal-cutter in the distance. I was quite glad to crawl back again; it is an eerie feeling to be in such a small space, far down in the earth, when one is not accustomed to it. We then set about preparing the camera and the flash-powder. The photographer had brought with him a regulation stand for the camera, but the only stand suitable to the circumstances was a small block of wood to raise the camera a few inches off the ground. We then placed a miner's lamp in the narrow passage along which the machine was to pass, and focussed as best we could by this light. Water had condensed upon the camera lenses, but this had evaporated before the machine came along.

When the machine arrived, we were disappointed to find that it more than filled up the end of our road, but it did not come up to the face of our opening. It was several feet within the low passage, and this meant that our light must be able to penetrate this low, dark passage for several feet. Picture the photographer sitting upon the floor, with a dark hole extending in front of him, the height of the hole being no greater than the space between an ordinary chair seat and the floor of a room. He is going to try and photograph a machine and two miners lying several feet within this low-roofed hole. Our hopes could only be sustained with some effort.

Extinguishing all the miners' lights and leaving the lens of the camera open, I set a light to the frayed end of the match in the powder tray. A moment of waiting, and then there was a sudden blinding flash of light. What an intense light! Surely we had secured a good picture! But remembering the reported failures of those who had already tried the same subject, we made several further attempts, each time increasing the amount of flash-powder. For the final attempt I warned all the men to close their eyes; even then the light was quite blinding, and one had the impression of light which seemed to last for many seconds. Between each ignition we had to take off our coats and use them as fans to drive the smoke out of the passage. The manager told us that we had certainly succeeded in producing a far brighter light than any of our predecessors had. We went off hopeful that when our plates were developed we should find that we had obtained good results. But development of the plates blasted our hopes. We had only secured a photograph of the ground immediately in front of the camera; our light had altogether failed to penetrate the lower passage.

From the appearance of the negatives we thought it possible that the flame had shot along the low roof and got in front of the lens. Our own passage was so low that when sitting upon the ground beside the camera our heads were just touching the roof, and by stretching out our arms we could touch the walls of the passage on either side.

There was nothing for it but to try again, with the flash-light farther back behind the camera, and so we arranged for a second expedition. On this occasion I had intended trying the effect of the flash-powder in one of the main roads where we had more room. I got a miner to crawl into a narrow seam, the end of which happened to meet the main road. We set the camera and prepared the flash-powder, but the powder refused to go off. One match after another was tried; the powder remained cold and indifferent. Coax it as we would, it would not respond, and so we came to the conclusion that the constituents of the powder must have been incorrectly mixed. This was decidedly disappointing after having travelled so far and having made all the necessary preparations.

The following day I made an experiment with the same powder and found that it ignited all right. It therefore occurred to me that it must have been the matches that were at fault. I then remembered that I had purchased the matches from a street-vendor on the way to the railway station. A simple examination proved the matches to be of foreign origin; the wax part was largely composed of wood, and the flame of the head was very poor. The explosion of the head was not sufficient to ignite the powder.

A third expedition was therefore called for, and on this occasion we went armed with several kinds of flash-powder and a liberal supply of British-made wax vestas. We first of all carried out the experiment in the main road which we had intended trying on the last visit. In this case the miner was several feet within the eighteen-inch seam, but we were in the main road, where we had plenty of air space for the flash-light. Having snapped a few photographs in this position, we proceeded to the place where one of the coal-cutting machines was at work. Here we exposed several plates, varying the amount of flash-powder at each exposure, and taking good care that the flame could not shoot out in front of the camera. Upon developing these plates the following evening, we found that we had secured a good photograph of the miner in the narrow seam off the main road; but those of the machine taken from the narrow passage were worthless. A reproduction of the main-road photograph is shown in the upper illustration facing page 230. This, however, was not what we aimed at. It was quite evident that we could never take the photograph of the machine from the narrow passage, because of the confined space in which to set off the flash-powder.

It then occurred to me to try acetylene gas. I called upon the manager of the business selling flash-powder and reported the results of my experiments. He quite agreed that there was no use in making any further attempt with powder. He too thought that acetylene gas was my only remaining hope, and he very kindly offered to lend me a large portable acetylene gas apparatus, a gasometer for four burners. He further volunteered to accompany me on this fourth expedition. As this gentleman was exceptionally tall, I tried to dissuade him; one of ordinary height finds it trying enough to crawl along the low, narrow passages. However, my friend was willing to take all risk; he had become interested in my difficulties and in my determination not to be beaten.

In order to do all that could be done on this trip, which was to be the final one, whether successful or not, I decided to make some preliminary experiments in the mine before the machine reached our road. I therefore made up a box with developing trays, all necessary chemicals, and a dark lamp. This would enable us to make some trial exposures and develop them in the mine before the machine reached us, so that we might act with some confidence when the machine did arrive.

Our burdens on this occasion were very considerably increased. In addition to the camera case, we had the bulky gasometer and its accompanying apparatus, while the box of chemicals was a rather awkward load. When we arrived at the mines, the manager said he had never met such persistent folk before; but I assured him that we too would acknowledge our defeat if we were beaten on this occasion.

It was most unfortunate that this night there had been

Down in a Coal-mine

In the upper illustration the miner was lying in a narrow working, while the camera was in the main road. This photograph was taken with a flash-light. It was impossible to take the lower photograph by such means; the coal-cutting machine and the two men were several feet within a working measuring only eighteen inches from floor to roof. (See chap. xv.)

some bad falls of the roof in the direct road, which we had travelled on the three former occasions. This necessitated our going down another shaft and approaching the coal-cutter by a much longer route. Here we were with all our additional burdens. I was truly sorry for my tall friend. Even with my previous experience, I found it a most trying ordeal. Several times I slipped upon a clay soil, and my box of precious chemicals nearly came to grief. We stumbled along as best we could, willingly accepting a bruised arm more than once, in order to save the apparatus. There seemed to be no end to this journey, and when we did reach the eighteen-inch seam, my friend said he really thought he could never manage to get out again. When we cooled down, our spirits revived, and we set about making a trial picture, to test the necessary duration of exposure.

We got one of the miners to lie along, in the narrow seam, in the position which the machine would occupy later. We then charged the acetylene apparatus and set the four burners alight. We tried one exposure of two minutes and another of five minutes. All lights were then extinguished, while I developed these two plates. The first was under-exposed, and the second one seemed to be about right. We prepared for the approach of the coal-cutter, as we heard it drawing nearer. Suddenly its business-like hum ceased; there had been a mishap to the machinery. It took the two machine men some time to get matters put right. Imagine working with the heavy parts of a machine, while lying on one's side in a space no higher than beneath an ordinary chair-seat!

When the machine at last came into position, I told the two men that I was sorry to find it would be necessary for them to remain perfectly still for five minutes, and that the same five minutes would seem to them to be more like a quarter of an hour.

> Time, with all its celerity, moves slowly on to those whose whole employment is to watch its flight.
>
> JOHNSON.

The coal-cutting machine practically filled up the opening to the seam, so that the two men could just show their faces—one at either end of the machine. It was no easy task to remain still for five minutes, and especially so with four blinding lights reflected full on to their faces. To make matters worse, an accident happened to the acetylene apparatus, the light suddenly went out, but shouting to the men to remain in the same position, we soon had the lights on again. Because of this mishap we thought it better to increase the time of exposure slightly, so that these miners had fully six minutes to remain motionless. How very ably they performed their task is witnessed by the lower illustration facing page 230, which is a direct reproduction of the photograph taken under these trying circumstances.

It will be understood that only the trial plates were developed in the mine. The negative from which the illustration has been made was developed above ground. Those who are engaged in practical photography will understand that this was not a simple case of throwing the developer upon the plate, fixing, washing and drying it, and then printing it on paper. The plate required a great deal of careful manipulation during the developing process. Fortunately my friend was a clever chemist, and knew exactly the right thing to do. The image was then transferred from one plate to another several times. One object in this was to equalise the light over the picture, and to this end the negative was placed at a certain angle to a powerful light at each exposure.

Many good photographs have been taken in coal mines, and without all this trouble; but, as far as I know, there has been no other picture taken in so narrow a seam. It was the limit of space which made the task so difficult. A friend has informed me that he saw a similar photograph shown in an electrical engineer's business book. The photograph he referred to was not only similar, it was the same; permission having been granted to reproduce my picture.

CHAPTER XVI

TELEGRAPHING PHOTOGRAPHS

An amusing story—All that the electric current can do—An early patent—Professor Korn's invention—The peculiar property of selenium—A simple analogy—The transmitting instrument—How it works—The receiving instrument—Its operation—Transmission of a photograph described—Utility of the invention—The speed at which it works.

WE speak of telegraphing money to a friend; but I hardly think, however green a country youth may be, that he will picture actual coin passing between one place and another by means of the telegraphic wire. Some of us may have heard the story of a countryman who, in the early days of the telegraph, bought a pair of boots for his wife, and thinking to send them immediately to her, he threw them into the air so that they fell astride a telegraph wire. Even the greenest of country cousins could not be credited with such simplicity to-day. How then are we going to send a photograph by means of the telegraph wire?

It is a simple matter telegraphing money. We pay the cash to the nearest postal telegraph office, and the officials transmit the intelligence, by ordinary telegraph, that a certain sum of money has been paid by the sender, and that a like sum is to be paid at the distant town to Mr. So-and-So. If you were to hand in a photograph and ask the postal authorities to transmit it to a certain distant friend, the case would be quite different. There is no saying but some day we may find the *Postal Guides* giving a rate of charges for transmitting photographs by telegraph. In any case, the actual transmission of photographs has been accomplished.

All that the telegraph can really transmit is electric currents. We must therefore control these currents by a photograph, and then cause these currents to reproduce the photograph at the distant end of the telegraph line. Even when we transmit speech by the electric telephone, we have only electric currents passing between the sender and the receiver. The vibrations of sound control the outgoing electric current, and the incoming current sets up corresponding vibrations and thus reproduces the original sound. But how is a photograph to be converted into electric currents?

One of the earliest patents taken out in America in this connection suggests a mechanical plan of reading the photograph. An impression of the photograph is taken on a gelatine surface, and then mounted on a drum or cylinder such as is used in the phonograph. Indeed, the whole idea is very similar to the idea of the phonograph. When the drum is revolved a needle rises and falls according to the relief and depression of the photo-gelatine surface, and the movements of this little needle control an electric current passing out to the distant telegraph station. The reproduction at the other end is purely mechanical. There is a needle point, which is set in motion by the electric current, so that it rises and falls in exact sympathy with the needle at the sending end.

This needle rests upon a plain wax cylinder, which revolves in synchrony with the sending drum. The needle therefore cuts depressions of varying depths as the wax surface passes under it. In this way a reproduction is made of the photo-relief gelatine surface at the sending end. I have seen prints of these early experiments, and while they were good, considering the mechanical means of reproduction, no one could call them facsimiles of the originals.

Professor Korn, of Munich University, has recently invented a much more perfect method. It is an instrument which uses a *pencil of light* instead of a cutting stylo, and can therefore do much finer work.

In order that the reader may clearly understand the action of Professor Korn's invention, he must first of all be able to appreciate the peculiar property possessed by a somewhat rare substance known as *selenium*. This is a non-metallic element which comes under the same category as sulphur. Selenium has a strange and almost magic property. Its resistance to the passage of an electric current through it varies according to the amount of light falling upon it. We can adjust matters so that in the dark no current will pass through it, but as soon as some light falls upon it, the electric current is able to cross it, and the more light, the more current passes.

Picture the selenium as being analogous to an electric bell push. A wire comes from the battery to the push, and another wire leads away from the push to the electric bell, and from there back to the battery. The circuit is complete, except that the push forms a break in the circuit. When the push is pressed, then the break is bridged over and a path is provided for the current to get from the battery to the bell. When the button of the push is released the circuit is again broken and the ringing of the bell ceases. Just so with selenium. When placed in the dark it is analogous to the push with the circuit normally broken, but when light falls upon the selenium the circuit is bridged and the bell rings. When the light is withdrawn it is analogous to releasing the push and thereby breaking the circuit once more.

Our analogy does not carry us far enough. In the case of the bell push, it makes no difference whether the push is closed by a child of five years or a powerful man of fifty years of age. The selenium, however, takes very particular notice of the power of the light operating it. If only a feeble light falls upon it, then the electric resistance of the selenium is only slightly reduced and a feeble electric current is allowed to pass. A powerful light breaks down the resistance of the selenium and permits a stronger current to pass. It is just as though the light withdrew a barrier from the path of the electric current, opening the barrier wider and wider as the light increases, and closing it again according to any reduction in the light. I have endeavoured to make this action of the selenium somewhat picturesque, as it is a peculiar property such as we do not meet with in everyday life.

We are now in a position to picture a selenium "push" or cell, through which the battery current must pass on its way to the telegraph line. This selenium cell is placed within a large dark cylinder in which there is only a small aperture. An electric lamp is so arranged that its light is focussed upon the small hole in the protecting cylinder. A pencil of light will therefore pass through and fall upon the selenium within. The selenium will at once become conductive, and will allow the battery current to pass out to the telegraph line. A constant light would give a constant current on the line, but we wish to control the light reaching the selenium and make it interpret the photograph. We therefore mount a transparency of the photograph upon a glass drum, which also surrounds the sensitive selenium. If a black part of the photograph happens to come between the pencil of light and the selenium, then all light will be cut off from the selenium and no electric current will be able to pass out from the battery to the line wire. If we can pass each part of the photograph in succession beneath the pencil of light, then we shall have the selenium's resistance constantly altering in accordance with the light and shade in the photograph, and the selenium in turn will cause an increasing and decreasing electric current to pass out from the battery to the distant telegraph station. A dark patch on the photograph will be represented by no current. A light patch, being transparent, will allow a lot of light to strike the selenium, so that the white parts of the photograph will be represented by the full electric current. Between the dark and the transparent parts of the picture there will be a great variety of shade. The more opaque these parts are, the less light will pass through to the selenium, and consequently the weaker will the electric current be.

It only remains to arrange that the whole of the photograph will be read by the pencil of light. The phonograph cylinder with its wax record gives us the exact motion required, but as it will not be convenient to move the pencil of light along the length of the cylinder, we must make the cylinder itself, with its surrounding photograph, move along from right to left, while it also revolves. In this way every part of the picture is brought in succession under the active pencil of light. We therefore have an electric current passing out to the telegraph line, and the variations in this current will exactly correspond with the variations of light and shade in the photograph.

Before watching the transmission of a photograph we had better pay a flying visit to the distant telegraph station and see how the varying electric current is to be translated again into light and shade. There we have an arrangement very similar in its general appearance to the transmitting instrument. We have a dark protecting cylinder with a small aperture through which a pencil of light may pass. In this receiving instrument the pencil of light is controlled by a small aluminium shutter. This little shutter, in its normal position, completely blocks the passage of the light. If the shutter is turned very slightly on its axis, it allows a little light to pass into the cylinder. The further the shutter is turned the more light passes, until it is full open, when the whole light passes into the cylinder. Inside the protecting cylinder is a drum carrying a sensitised photographic film; the movement of this drum is identical with the movement of the transmitter's drum.

The pencil of light falling upon the photographic film will affect it just as an ordinary photographic plate is affected in the camera. In the ordinary camera the whole plate is acted upon at one time by the light and dark image falling upon it. In this photo-telegraphic[1] apparatus the picture is gradually built up by the pencil of light travelling across the photographic film in successive lines.

It only remains to control the movement of the little aluminium shutter, the position of which determines the strength of the pencil of light falling upon the sensitised surface. The little shutter is turned by the electric current coming in from the distant transmitter. Some readers may be curious to learn how this turning of the shutter is accomplished. Those who have read *The Romance of Modern Electricity*, which has already appeared in this series, will remember that when an electric current passes through a coil of wire placed between the poles of a magnet, the coil, if free, will turn round and seek to set itself at right angles to the plane of the magnet. If the current be only a weak one the coil may be arranged so that it will only be turned a very little by such a current, but as the current is increased the coil is turned further. In Professor Korn's receiving instrument a simple coil of copper wire has the little aluminium shutter attached to it. It is so placed that when the coil is turned by the electric current the little shutter acts towards the pencil of light just as a water-tap acts

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[1] Professor Korn calls his pictures tele-photographs, but as we already use this word in connection with photographs taken by means of a tele-photo lens, it might be better to call Professor Korn's pictures photo-telegrams, or at least to speak of his process as being photo-telegraphic.

By permission of Professor Korn, Munich University

TELEGRAPHED PHOTOGRAPHS

These photographs are just as they were received by the electric telegraph. The left-hand picture is of the Crown Prince of Germany, while the other is of Professor Korn, who invented the apparatus by which photographs may be transmitted across many hundreds of miles of country. (See chap. xvi.)

towards the water. The further this little shutter is turned the more light is permitted to pass.

If no current comes in from the distant station, the shutter will remain in its normal position and thus prevent any light from falling upon the photographic film. The strength of the electric current sent out by the transmitter will determine the amount of light which the shutter will allow to pass into the protecting cylinder.

In this simple manner the variations of the incoming electric current are translated into variations in the strength of the pencil of light. The revolving photographic film upon which this pencil of light falls records all the variations of light and shade. The photographic record will not be visible until the film has been chemically developed, but in describing the transmission of a photograph I shall suppose, for the sake of simplicity, that the image is immediately visible.

As our demonstration is only to be in imagination we can be in two places at once, so that we may watch both the transmitting and the receiving apparatus, which are placed in two towns separated by hundreds of miles. Everything is in readiness, and the two cylinders, one at either station, are set revolving at the same time. It is necessary that the cylinders move in exact sympathy or synchrony, and there is a special arrangement to ensure this. The photograph we are about to transmit is one of the Crown Prince of Germany, as shown in the left-hand illustration facing page 240.

The pencil of light in the transmitter first falls upon the grey background, which permits a certain amount of light to pass through it and affect the enclosed selenium. A corresponding electric current is allowed to pass out to the distant station, where the little shutter, under the influence of this electric current, is turned slightly round, so that a faint pencil of light is allowed to pass and fall upon the photographic film. This leaves a record of medium activity, or grey, upon the developed film. This condition of things continues until the hat in the photograph comes under the pencil of light. Here a stronger light at once reaches the selenium, a more powerful electric current reaches the distant station, and the shutter, turning still further round, permits a stronger pencil of light to fall upon the photographic film, causing it to become black. Then when the transmitting pencil of light falls upon the black ribbon band of the hat, almost all light is cut off from the selenium; practically no electric current reaches the distant station, so that the little shutter is left to block the way of the pencil of light in the receiver. The photographic film will remain unaffected, and therefore transparent on the negative. And so on and so on, until the whole of the photograph has passed beneath the transmitting pencil of light and been reproduced as a negative at the distant station. This negative may then be used to print off any number of positives desired. There is necessarily a slightly lined appearance in the reproduced photograph, but from a little distance this is not seen, and, indeed, it does not interfere in any way with the portrait.

From this somewhat crude description it will be seen that all the variations of light and shade in the original photograph may be reproduced at a far distant station,

TELEGRAPHING PHOTOGRAPHS

Photographs have been transmitted by Professor Korn's apparatus over a distance of many hundreds of miles.

It is not at all likely that we shall in the future be continually telegraphing our photographs to our distant friends, but there are many useful purposes to which this invention may be put. The police authorities may have occasion to telegraph the photograph of a criminal from one city to another for the purposes of identification. How much more helpful than a mere word description! Then the pictorial papers may have photographs of important events immediately telegraphed from long distances.

It is obvious that the speed at which such photographs may be transmitted will not be dependent upon the celerity of the electric current, for it is at its destination "in less than no time." The speed of the transmission of a photograph will depend upon the sensitiveness of the selenium cell, and also upon the rapidity with which the shutter in the receiver may be operated. Complete photographs have already been sent in the space of ten minutes.

The right-hand illustration opposite page 240 is a photograph of the inventor himself as it was reproduced by the electric telegraph at a distant station.

A technical description of this photo-telegraphic apparatus is given by the author in the journal *Electricity* (London), Vol. XXI, Nos. 23, 24, and 25, 1907.

CHAPTER XVII

NATURE'S CAMERA

The eye compared with the camera—How Nature protects her camera—The iris and the iris diaphragm—The inverted image—Why do we not see things upside down?—The true function of Nature's camera—Thousands of images formed by the eye of a beetle—A shadow cast upon the retina appears to be upside down—An interesting experiment—Why the image in the camera is inverted—The bending of light demonstrated—The camera lucida again—Photographic action of the retina—John Dalton's colour-blindness—Interesting colour experiments with the eye—Why we have two eyes—The stereoscope.

WE may admire the very excellent workmanship in the modern camera; the beautiful images it produces; the wonderful amount of light it lays hold of, so that it can snap the image of a flying train. Yet all sinks into insignificance when we once realise the beauty of *Nature's camera.* The modern camera looks quite like a rough copy of the construction of the human eye.

In Nature's camera we have the dark chamber, the lens for focussing, the iris diaphragm, which opens and closes, and we have the sensitive or sensitised screen with an image produced upon it.

In a camera we must either move the lens or the focusing screen to and fro, in order to bring the image to a focus. An opera glass, a telescope, a microscope, a magic lantern, have all similar arrangements for altering the relative positions of the lenses. Nature's camera far surpasses all such devices. It would not be convenient to move the back of the eye to and fro, or to give the lens a similar motion, so the lens alters its curvature to suit the necessary focus. If we are looking at an object very near at hand, the *crystalline lens* becomes more convex, especially the front; or, in simpler language, it bulges out. If viewing a distant object, the lens becomes flatter. This *accommodation* is obtained by the combined action of a circular ligament which holds the lens in position and a circular muscle attached to the capsule surrounding the lens. We may picture the crystalline lens as being made of a transparent jelly-like substance which is highly elastic.

It may be helpful to take a look at the model of the eye illustrated opposite page 248. The first photograph shows the complete eyeball. This delicate camera of Nature is well protected in the bony eye-socket, which is lined with fat, so that the eyeball may be protected and easily moved. The movements of the eyeball are controlled by six muscles attached to it, and it is any irregularity in these muscles or in their movements which causes squinting. The ends of some of these muscles may be seen on the model.

The eyeball is further protected by the eyelid and also by the eyelashes. The latter assist to prevent dust falling upon the eye, while the eyelids in conjunction with the tear-ducts keep the exposed part of the eye moist and clean. The eyebrows protect the eyes against the possibility of perspiration trickling down from the forehead.

The eye has a still further protection. The eyelids are lined with a soft mucous membrane, and this not only lines the eyelids, but it comes from the upper eyelid right over the exposed part of the eyeball and joins the lower eyelid. This skin is known as the *conjunctiva* and serves as a sensitive protective covering to the eyeball.

The white substance forming the outer coating of the eyeball is quite opaque to light, and is called the *sclerotic*. It forms the body of the camera.

Under the white coat is another coating which is largely composed of blood-vessels. The space between these vessels is filled with cells containing granules of very dark brown or almost black pigment. This dark lining absorbs all the light which falls upon it, so that there will be no reflection inside the dark chamber. This second coat is called the *choroid*, and is analogous to the black lining of the camera. If this black lining completely surrounded the interior of the eyeball, no light could enter. But in front of the crystalline lens it forms a curtain with a window or aperture in it. This curtain, which opens and closes, is called the *iris*, and the aperture or space at its centre is called the *pupil*. It will be observed that the pupil is not a material thing; it is merely the hole in the iris curtain. If we only possessed the pupils of our eyes, we should be in the same predicament as the Irishman, already referred to, who declared he had nothing left in his wardrobe but the armhole of an old waistcoat.

It is the iris which gives colour to the eye, and the colour is simply dependent upon the amount of dark pigment interlining the iris. As it contains less or more pigment, the eye appears blue, grey, brown, or black.

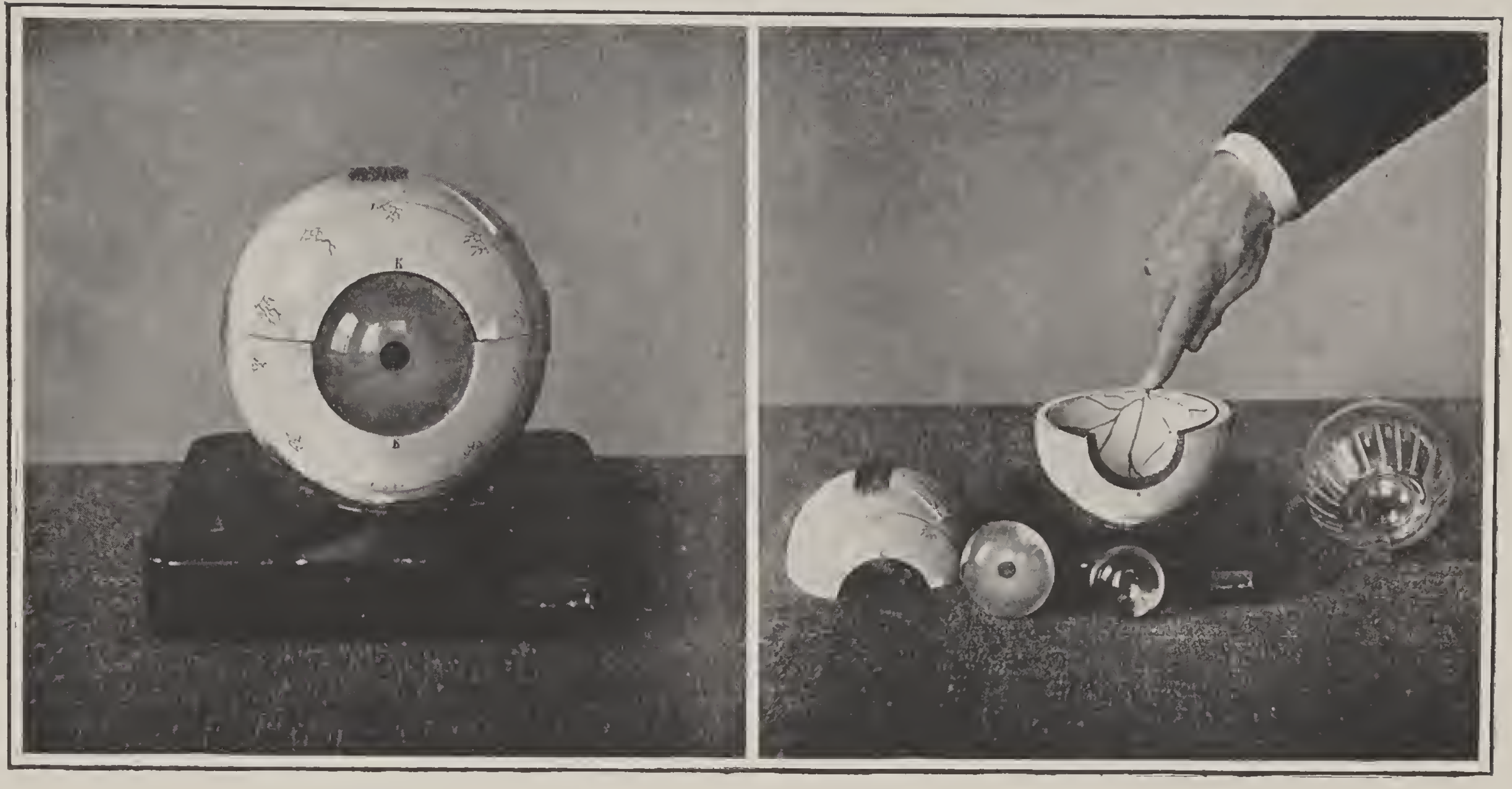
While the iris diaphragm in a modern camera is a rough imitation of the human iris, the purpose it serves is not the same. In Nature's camera the iris regulates the amount of light which is to enter the eye; in a dull light we require more of it to stimulate the nervous system of the eye. If a strong light falls upon the eye, the pupil automatically becomes smaller. The involuntary motion of the iris is therefore to regulate the amount of light entering the eye. The iris diaphragm in the modern camera certainly regulates the amount of light entering the camera too, but that is not its object. The purpose of "stopping down" the camera lens is to get as sharp an image as possible. If the photographer opens the iris diaphragm to its full extent, he gets the maximum of light. This is an advantage, but some of the light is passing through the outer part of the lens, which does not focus the rays of light so perfectly as the central part of the lens does. The photographer's object is therefore to use only that part of the lens which gives the most perfect image. Having cut off so much of the light, he has to give a much longer exposure.

The operation of the iris in Nature's camera is very beautiful. The closing of the iris is somewhat similar to the method adopted in a lady's work-bag, in which a cord is pulled to close the top. In the iris there is a little circular band of muscle fibre, near the margin of the pupil, and when this contracts it closes the aperture. Some other muscle fibres, placed in the iris like spokes in a wheel, are capable of contracting and thus drawing the curtain open. The action of the iris may be observed by looking at one's eyes in a mirror, and at the same time moving a lighted taper nearer to and farther from the eyes.

The photographer takes great care of his lenses, protecting them against possible injury. What does Nature do for her camera? The crystalline lens is immediately behind the open window of the iris, and it would not do to leave the little lens unprotected. There is a protecting body called the *cornea.* It is just like a transparent window set in the white sclerotic coat. It is of necessity transparent, and is built up of layers, somewhat after the fashion of an onion's construction. The space between this cornea and the iris is filled with a watery fluid, known as the *aqueous humour.*

Looking at the right-hand illustration on the opposite page, the iris with its protecting cornea is seen leaning against the base to the left-hand side. Close to this, leaning against the centre of the base, is the crystalline lens. To the right-hand side of the photograph is seen a large glass globe, which represents a jelly-like substance that fills the whole interior of the eye; this is called the *vitreous humour.* Inside the opened model, some lines are painted to represent the network of nerves connected with the *retina*, which is a complicated structure very sensitive to light. The inside of the model is white in order to show these nerves, but in reality the inside of the eye is black. The nerves merge together and leave the eye at the point indicated by the finger. They form the *optic nerve*, the fibres of which carry nervous impulses to the sensorium, or brain, in which the sensation of vision takes place.

To sum up; the light enters the cornea, passes through the pupil of the iris, then the crystalline lens, through the jelly-like vitreous humour, and finally falls upon the retina, changes in which excite the optic nerve fibres. In



A Model of Nature's Camera

The photographic camera is very like a rough imitation of the human eye. (See chap. xvii.)

this way an image of the outer scene is depicted upon the retina, or sensitive screen. Certain nerve impulses reach the brain, and there the vision picture is interpreted.

There is a difficulty which often arises here. Like the image in Battista Porta's camera obscura, or in any camera, the image is standing on its head. Why then do we not see things upside down? This has proved a stumbling-block to many, and yet I think there is no real difficulty in arriving at a common-sense view of the matter.

I remember, many years ago, hearing a lecturer questioned upon this point, and his reply seemed quite unthinkable to me. He believed the inversion of the image to be rectified by a crossing of the optic nerve on its way to the brain. I have before me, as I write, a recent number of an American literary journal, in which there is an article dealing with this theory of vision, in which the crossing of the nerve fibres is said to solve the problem of the inversion difficulty. It is stated that this theory "has gained wide acceptance among scientists." I can hardly credit this statement; a common-sense view of the matter makes this theory quite unnecessary.

If we think for a moment of the part which Nature's camera plays in the act of vision, we find that it is in reality only an optical instrument. It focuses the ether waves of light upon its retina, and by some means or other the retina is thereby stimulated, causing nerve impulses to be transmitted to the brain. The eye is therefore merely a receiving instrument; it does none of the interpretation; that is all done at the other end of the optic nerve in the brain. What the brain interprets is the nerve impulses, not the image on the retina. It is therefore a matter of no moment whether the image on the retina is upside down or sideways up; it would make no difference if the image on the retina was entirely absent, as long as the light waves could stimulate the retina. By unconscious experience we have learned to interpret the sensations in the brain; we take no account whatever of the manner in which these sensations are set up; it is therefore quite immaterial to us whether or not there happens to be an inverted image produced during the process of vision.

The eyes of some beetles are so constructed of a myriad of tiny lenses that no fewer than twenty-five thousand images are simultaneously thrown upon the nerve endings of the eye. This has been very clearly proved by taking a photo-micrograph through the eye of one of these beetles. Are we to suppose that when this beetle meets another solitary insect it sees an army of twenty-five thousand insects approaching? Certainly not; the beetle is not conscious of these manifold images. But like us, only in a very different form of consciousness, the beetle will interpret the nerve sensation and not the incidental myriad of images.

If a man stands upon his head, then we see him upside down, as he is, because our sensation is reversed from that which we have when he stands upon his feet. But suppose the man was standing on his feet, and I could, by some means or other, cause an upright reflection of him to fall upon the sensitive screen of your eye, just as in a mirror, then you would see him upside down, while he still stood upon his feet. We cannot perform this experiment, but we can arrange a very simple experiment which completely proves that this would be the case.

Take a piece of cardboard; a post card will serve the purpose. Pierce a hole at the centre of the card, using an ordinary pin. Hold the card up between one of your eyes and the light, keeping the other eye closed. Then look through the small pinhole, having the card a few inches from the eye, and at the same time bring the head of a pin close in front of the eye, holding the pin in an upright position. This will cause an upright shadow of the pin to fall upon the retina, and you will see the pin upside down. Indeed, if you were not holding the pin yourself you would believe that it was being held upside down. This experiment is well known, and is easily performed. It is best done with no other light in the room but the one which is being looked at through the card. The pin should be held quite close to the eye, indeed, touching the eyelashes. Keep the head of the pin up, and there is no danger of hurting the eye. A pin with a good large head is best.

In passing away from this subject, I would remark once more that it is not the inverted image on the sensitive screen which the brain interprets; it is the nerve sensations reaching the sensorium.

In one of the earlier chapters I passed over the fact of the inverted image in the camera obscura, remarking that no doubt it would be patent to most readers why the image is inverted, but that the matter would be fully dealt with in this chapter. It seems as though there could be no possible confusion here.

If a man looks at his reflection in a looking-glass, he does not see himself upside down. He sees an exact reflection of himself, his left hand, however, becoming the right hand of the reflected image. It is just as though we had made a contact print of the man upon the glass. If, on the other hand, a man stands in front of a camera, the case is quite different; his image appears inverted upon the ground-glass screen. Why?

Imagine the lens of the camera to be at about the height of the man's waist. Light is reflected from his face in all directions. Some rays pass over the top of the camera, some enter the lens. It is quite apparent that all the rays entering the lens from the man's face are travelling in a downward direction. They pass through the lens and necessarily continue in a downward direction, so that they naturally fall at the bottom of the ground-glass screen inside the dark chamber. In similar fashion, the only rays of light reflected from the man's boots which can enter the camera are travelling in an upward direction. These rays passing in at the lens continue in their upward direction till they strike the top of the ground-glass screen in the camera. In this way an image of the man's boots appears at the top of the screen, while his head appears at the bottom of the screen. This inversion is bound to occur when an image is formed by rays of light passing through a small aperture.

In some earlier chapters we have considered the bending of light by means of glass prisms. We have all seen the apparent bending of a stick when placed partly in water and held at an angle. Those of us who have tried to spear flounders around the sea-coast know how necessary it is to hold the long spear perfectly perpendicular, or else we are sure to give the spear a wrong thrust.

The bending of light is very clearly demonstrated in the illustration opposite page 254. The left-hand illustration shows that the penny is "round the corner." The experiment would still have been possible if the penny had been placed quite out of sight. As the demonstration was to be by photography, and not by direct observation, I thought it better to show the exact position of the penny. Having taken this photograph, we let the camera, basin, and penny all remain in exactly the same positions. We carefully fill the basin with water and then take the second photograph. The penny is now quite clearly seen, but it is really "round the corner," just as it was at first. The water has bent the rays of light round the edge of the basin. Rays of light passing out from the coin are so bent over the top of the basin that they reach the eye. Now the eye is not a conscious organ; it takes no notice of the fact that the rays of light falling upon it have been bent on their journey. We therefore see the penny as though it were lying further back in the basin; that is merely our interpretation of the sensation received.

Suppose we placed a crack rifle shot in the position just occupied by the camera. We could safely offer him a handsome prize if he could strike the penny without breaking the basin to get at the coin. Suppose we had a strong iron basin, we could let the rifleman shoot all day at the coin, and he could never hit it; it is "round the corner." He is really seeing the penny in a position which it does not occupy.

When rays of light form an image upon the eye, we take no notice of how these rays may have been bent on their way; we simply interpret the nerve sensation, and we see the object in a position it would naturally be in to form the said image provided there had been no bending of the rays. This is why the artist using the camera lucida sees an image of the landscape upon the paper before him, while his friend looking directly at the same paper sees nothing but a blank paper. The artist alone sees the picture, because the rays of light reflected by the landscape are bent by the glass prism and cause an image to be formed upon his eyes.

It will be of interest to see how the "sensitive plate" is operated in Nature's camera. Is it a photographic action?

It was supposed for a very long time that we had three sets of nerves in the retina, one of which was sensitive to red, another to green, and the third to violet rays of light. This theory seemed to make matters fairly clear, but the three sets of nerves, or nerve endings, could not be found in the retina.

Within recent years it has been discovered that in the frog's eye the retina secretes a substance, which is of a purple colour, and has been named *purpurine*. The purple matter is bleached to a dull grey by light. Here we have the chemically prepared photographic plate! This photographic substance is held in the meshes of the retina, which spreads over the interior of the eye. Any chemical change in this purpurine is appreciated by the nerves and immediately telegraphed to the brain. In the human eye, and more especially in the part most sensitive to light, the so-called yellow spot, there is no purple stuff,

Seeing round a Corner

The only difference between these two photographs is that the basin in the left-hand picture has no water in it, whereas that in the right-hand picture has. The coin and basin are lying in exactly the same position in both photographs, and the camera was in no way disturbed. (See chap. xvii.)

but there are probably other colourless chemical substances.

This theory appears to solve many problems. What about colour? Many persons cannot see the colour red; we therefore suppose that some chemical ingredient is wanting. It is quite possible that many people go through life without the knowledge that they cannot see red as other people do. Even such an observant man as the great John Dalton, the founder of modern chemistry, was twenty-six years of age before he discovered that he was "colour-blind." The occasion of his finding out this defect in his vision is very amusing. Thinking to take his mother home a useful birthday present, and seeing in a shop window a pair of stockings marked "silk and newest fashion," Dalton promptly secured these as a suitable gift. He was very surprised when his mother said, "Thou hast brought me a pair of grand hose, John, but what made thee fancy such a bright colour? Why I can never show myself at meeting in them." Poor Dalton said that the stockings being of a "dark-bluish-drab" he considered them to be a very proper sort of go-to-meeting colour. His brother Jonathan was called in to settle the disputed point, but he at once agreed with John, and the two brothers came to the conclusion that the old lady's sight was strangely out of order. Deborah, thinking that it was her sons' sight that was at fault, consulted some of the neighbouring wives. She soon returned with the verdict "Varra fine stuff, but uncommon scarlety." Shortly after this Dalton directed the attention of the scientific world to this "extraordinary fact relating to the vision of colours."

There is another phenomenon which seems to bear out this theory of the photographic chemicals in Nature's camera. It is a well-known fact that if one stares steadily at a red colour for a minute, one will then see a sheet of white paper appear green. Just as I write these lines I have beside me three sheets of coloured glass—a red, a green, and a violet. I have been looking steadily at a bright incandescent gaslight through the red glass, and now when I look directly at the white paper upon which I am writing I see it a decidedly greenish-blue colour. I now look at the light, for a minute, through the green glass. When I look back to my paper it is a strong crimson-pink; the effect in this case is to me more striking than the first. Now I look through the violet glass, and then at my paper, which now appears a decided yellow. Of course, these effects might be explained by the theory of three different sets of nerves, one set of nerves becoming fatigued by looking at the red, and so on. We have no evidence of there being three sets of nerves, and the chemical theory seems to me much more reasonable. We imagine this chemical substance being acted upon by red rays, causing all the red ingredient to be decomposed. We immediately throw a white light upon this altered substance, and while the white light is composed of red, green, and violet rays, its red rays can find no chemical substance to act upon. Red is therefore absent from the sensation produced, and we see a combination of the other two rays, a greenish blue, and so on with the others.

Now it seems quite reasonable to suppose that in a case of colour-blindness the eye itself is quite normal, but there is a defect in the chemical laboratory which produces the sensitive stuff, and the particular ingredient which is affected by red rays is not manufactured at all. We therefore believe that the part played by the retina in regard to vision is a purely photographic process.

Nature has provided us with two separate cameras, not simply that we may have a spare one in case of accident, nor yet only that we may have a wider range of vision. Each eye produces a different picture; it looks at an object from a slightly different position from its neighbour. It is the combination of the two pictures which gives us the impression of the solidity of things.

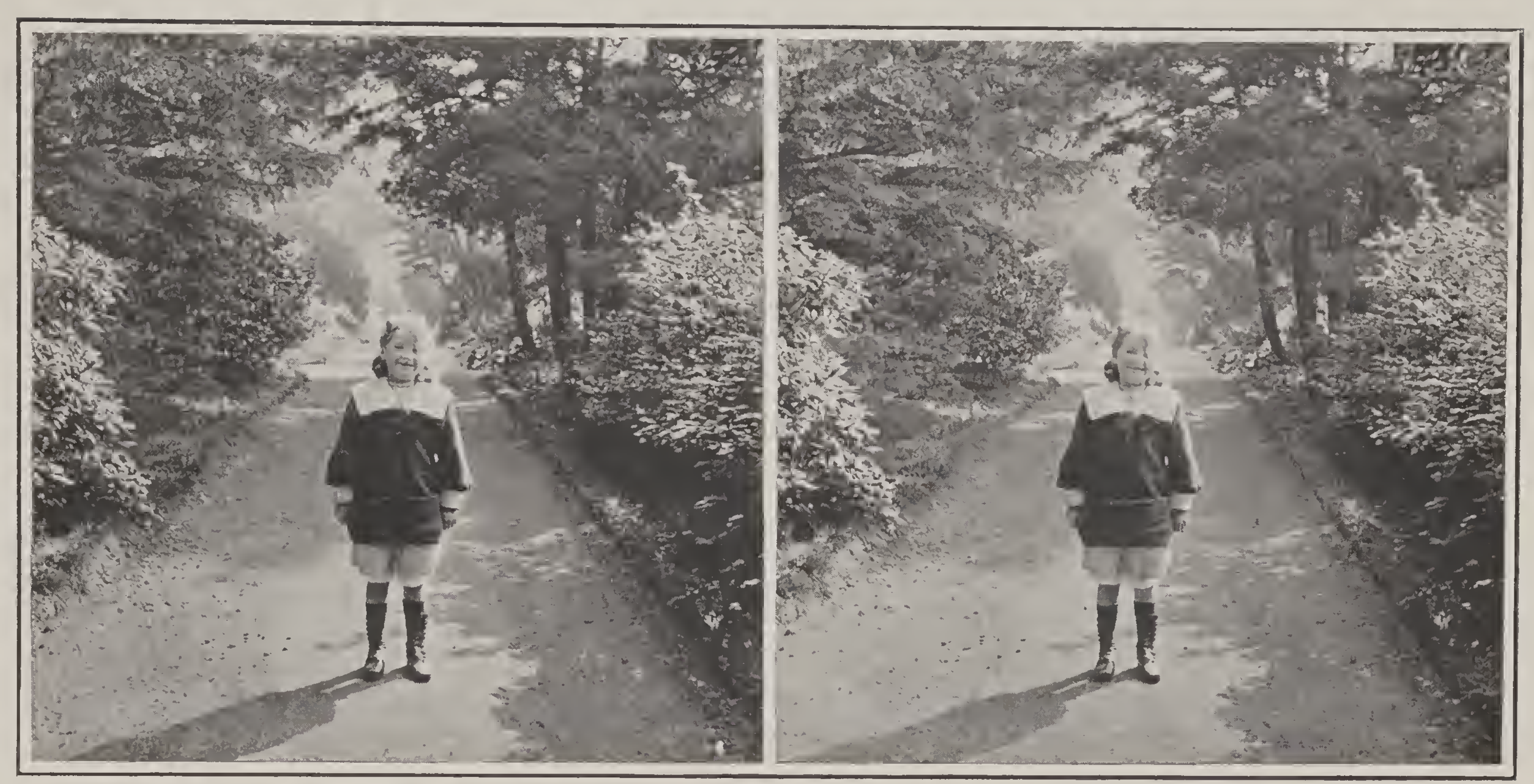
Hold a pencil up in front of you, close one eye, and let the pencil cover some distant object from view. Keeping the pencil in the same position, look at it with the other eye; the pencil appears in quite a different position. You thus observe that the two pictures produced in your eyes are different from each other. Your left eye really sees more of the one side of an object than the other, while the right eye sees the other side best. This is quite apparent in the illustration opposite page 258. These two photographs have been taken by a double camera, or practically two cameras. The two lenses are mounted a little distance apart, just as our eyes are. It is quite apparent that the camera which took the left-hand picture has had a different view from the camera which took the right-hand picture. In the latter the little girl's head appears quite close to the left-hand bank, whereas in the other picture her head appears close to the opposite bank.

Here we have imitated Nature's twin cameras; we have produced two different images just as our eyes do; but how are we to combine these two effects? When you look at the illustration, each eye sees both pictures. We must throw each picture separately, the one on the right eye and the other on the left eye. Some people are able to adjust their eyes in such a manner that the two pictures each fall separately upon the proper eye, but to most of us this is not easily accomplished. We are all familiar, no doubt, with the simple instrument known as a *stereoscope.* It consists of two lenses with a dividing partition, and is so arranged that when one looks at a stereoscopic pair of photographs, such as that shown in the illustration, each eye sees only its own picture. The pictures are in a sense recombined in the brain. We then have two different views upon the sensitive screens of our eyes, and we see the objects stand out in bold relief, just as we do in viewing the original objects.

When one uses a stereoscope for the first time, one is very much surprised at the splendid perspective and the enhanced reality of the scene.

I remember on one occasion, before stereoscopes were so well known as they now are, I found an enthusiastic amateur busily mounting duplicates of some of his photographs on stereoscopic cards. He was very disappointed when I pointed out that his work was useless, and that he must take two different photographs, each photograph being really a different view of the scene.

Quite good stereoscopic photographs may be taken by a single camera, provided one arranges a base upon which the camera may be moved into two positions. First of all one photograph is taken, and then the camera is moved along so that the lens is two and a half inches farther to



Stereoscopic Photographs

The stereoscopic camera takes two photographs, each being a slightly different view. This is just what our eyes do. When these two different pictures are thrown, one on each eye, the effect is most realistic. Observe that the child's head is close to the right-hand bank in the left-hand photograph, while her head is close to the opposite bank in the other photograph. (See chap. xvii.)

one side, and a second photograph is taken from that position. It is much more convenient, however, to have the camera divided into two and the two lenses placed two and a half inches apart. The two pictures are then taken simultaneously, thus permitting of instantaneous photography.

Some readers may have seen a stereoscopic photograph of the moon, and yet it must be apparent that any two photographs, taken by a stereoscopic camera, of so distant a body, must be practically the same picture. The way in which the stereoscopic photographs of the moon have been taken has been to take two separate photographs at different periods, for when the moon has made a circuit round the earth she does not arrive back at the very same position from which she set out. Suppose we had a complete circle drawn in the heavens, around the earth, and fixed in a permanent position. The moon sets off from one point upon this circle, but when she returns we find that she is either above or below this line; we therefore get a slightly different view of her. Therein lies the photographer's opportunity of securing two photographs for his stereoscope.

CHAPTER XVIII

SOME INTERESTING ACHIEVEMENTS

The largest photograph in the world—How it was developed—Enlarging photographs—An amusing incident—A gigantic camera—The photographer inside the camera—Tele-photography—Good pictures taken from a distance of one mile—Nature photography—Ballooning and photography—Photographing the New York subway—Calculating exactly when a photograph was taken—Faked photographs.

WHILE America is the country of big things, Germany can boast of having produced the largest photograph in the world.

The accompanying illustrations (see frontispiece) show how this gigantic photograph was handled. In the larger illustration we see the great photograph mounted on a large wheel, or drum, having a circumference of forty-one feet. A number of very large tanks had to be constructed so that the gigantic print might be developed, cleared, fixed, and washed. These tanks were so heavy that it was necessary to have them on wheels, and to construct a miniature railway track, along which they might be moved as desired. The washing tank required to be fifty feet in length, six and a half feet wide, and two and a half feet deep. Where is the dark room to hold such enormous developing baths, etc.? The only way out of the difficulty was to develop the photograph in the open air during the night.

Some idea of the magnitude of the task may be gathered from the fact that more than ten thousand cubic feet of water was used in washing the print.

The subject of the photograph was the Bay of Naples. The complete panoramic picture measured about forty feet by five feet. It is evident that no camera could hold a plate or film of such a size. The method of obtaining the photograph was as follows:—

First of all six panoramic views were taken; each of these measured ten and a half inches by eight inches. These six photographs contained the whole detail of the final picture; joined together they would form a miniature of the gigantic photograph. From each of these six photographs an enlargement was made. The process of enlarging is well known, but will be explained a little later. Each enlargement measured about six and a half feet long by five feet, and to obtain these it was necessary to have a very large lens, measuring one foot in diameter. While these enlargements were made separately, they were not made on separate sheets of paper. One long sensitised paper, the complete foundation of the final picture, was prepared. Then an enlargement of the first negative was made directly upon this paper, next to that a similar enlargement of the second negative, and so on, until the whole six enlargements had been made in succession. This must have been a difficult task, for the picture is not seen upon the paper until the complete bromide print is developed later. How very ingeniously this difficulty was overcome was shown by the final result. It was practically impossible to detect the boundary line of any two plates.

Then came the task of developing the hidden or latent image of the complete photograph. From the illustration it will be seen that twelve men were required to look after the developing of this one great photograph. The man on the top of the ladder is projecting iced acetic acid, from a hand-pump, on to a part of the photograph which is already sufficiently developed; the action of this acid being to stop development. At other parts of the photograph, where the image was faint, it was found necessary to force the developing by applying an energetic developer by means of sponges.

In the smaller illustration below, the print is being unreeled from the developing wheel into the clearing bath, and this illustration will probably give the reader a better impression of the length of the photograph. A large number of basketed jars containing the different chemicals will be seen at the side of the developing wheel, large quantities being required to fill the different tanks. Altogether the production of so large a photograph is remarkable.

It is possible that some readers may not be familiar with the process of enlarging. The method is very simple. It will be evident that if one were to use a negative as a magic-lantern slide, one could project an image on to a white sheet. Instead of throwing the image on to an ordinary lantern sheet, let us replace the insensitive sheet by a large piece of sensitised photographic paper. All the variety of light and shade will be faithfully recorded by the photographic paper. We might use ordinary printing-out paper if the source of light we were using was good strong daylight, and provided we could depend on a sufficiently constant light. In Great Britain, however, it is usual to employ a bromide emulsion paper, which is very much more sensitive to light, and with which an artificial source of light may be used. It has already been noted that the image upon the bromide paper is invisible until it is chemically developed.

If the photographer, using bromide paper, desires to use daylight, he darkens his room by means of a shutter or cloth screen, leaving only a small window into which the back of his camera will tightly fit. He now uses his camera as a daylight magic lantern. He places the negative of which he desires an enlargement in the back of his camera, just where the ordinary photographic plate goes. The daylight enters the camera through this negative, and an image is projected into the dark room. He focusses this image upon a piece of paper, and when it is sharp he replaces the paper screen by a sheet of bromide paper. After a suitable exposure the bromide paper is developed and a record of the enlarged image is secured.

When it is desired to enlarge pictures by means of artificial light, then a special projecting apparatus is used, this being simply a specially constructed magic lantern.

It is an interesting fact that a negative film may be enlarged directly by chemical means. The negative is first of all placed in a bath of ammonia, and in about two hours the film is freed from its glass support. The film then distends, the process being hastened if necessary by the addition of a little hot water. The enlarged film is then floated on to a large glass plate and allowed to dry. It is obvious that the whole limit of enlarging by this process cannot be very great, probably not more than twice the size of an ordinary negative. Then again, in the event of any accident, the original negative is lost.

This distension of the negative film reminds me of an amusing incident which happened quite accidentally. A photograph had been taken of some friends, and in the amateur's haste to get the negative dry enough to print from he placed it near a fire. The negative film distended, but only in one direction, and the resulting prints were very comical, every person was so short and stout. The effect was exactly that seen in a curved mirror, such as is sometimes used at exhibitions for affording amusement.

I believe Glasgow can boast of having possessed the largest camera in the world. Many years ago the late John Kibble, who erected the handsome greenhouses, known as the "Kibble Palace," in the Botanic Gardens of Glasgow, was the possessor of an immense camera. It was mounted on wheels and drawn by a horse ; the whole arrangement being in appearance rather like a furniture removal van. This camera was used in the days of wet collodion plates, so that it was necessary to prepare the plates immediately before taking the photographs, and then develop the plate immediately afterwards. Where are the plates to be prepared and developed ? Inside the camera itself. It is curious to think of the photographer and his assistant being both closeted inside the camera while a photograph was being taken.

First of all the glass plate had to be coated with the sensitised chemicals, in the method described earlier under Scott Archer's name. Then the picture had to be focussed on a white screen, in order to find the exact position in which to place the photographic plate. While the plate was being exposed the photographer and his assistant had to keep clear of the projected image. Then when it was deemed that the plate had been sufficiently exposed, the plate was straightway developed.

Some excellent photographs were taken, by this gigantic camera, in the busy streets of Glasgow. It is indeed remarkable that it was possible to take instantaneous photographs with so large a camera.

An elderly gentleman, who was a contemporary of Kibble, tells me that he was inside this huge camera on several occasions, and the arrangements for preparing and developing the plates were most ingenious.

Facing page 284 we have an illustration of tele-photography. The upper illustration is a photograph of St. Alban's Abbey taken from a distance of one mile. The picture of the abbey itself is necessarily very small, and one cannot see much detail.

The lower illustration is a photograph taken from exactly the same position, one mile distant, but this has been taken through a tele-photo lens. In this picture one sees the abbey very distinctly. It is difficult to realise that the trees, so clearly seen in the foreground, were nearly one mile away from the camera. The little square marked off in the upper illustration shows exactly how much of that photograph is contained in the lower illustration.

Tele-photography is practically photography through a telescope, the tele-photo lens acting as the telescope. There are decided advantages in the tele-photo lens. It admits far more light than a telescope would do, and it is so constructed that its focus does not require a long extension of the camera.

There are many useful applications of tele-photo lenses. We shall see one great use of these in the chapter on *photographing the stars*. Tele-photo lenses have also been of much service in photographing the architecture of inaccessible parts of a building and mountain scenery. Another interesting application is in photographing birds in the air or in their nests. One great advantage in natural history work is that the photographer can obtain a near view without going close up to the animal and possibly disturbing it.

In connection with *nature* photography, the two brothers Kearton (England) have done a great deal of most interesting work. Their photographs of birds and nests are well known through their lectures and writings.

In looking at the illustrations which they have published from time to time, one sees the great advantage of getting actual photographs of birds upon their nests, etc. It would be an interesting occupation to compare many artists' drawings of birds with the actual photographs now obtained. Our present interest, however, lies in the taking of the photographs.

It is quite evident that the Keartons are enthusiasts. They relate that in their photographic expeditions they "have slept for nights together in empty houses and old ruins, descended beetling cliffs, swum to isolated rocks, waded rivers and bogs, climbed lofty trees, lain in wet heather for hours at a stretch, tramped many weary miles in the dark, spent nights in the open air on lonely islands and solitary moors, endured the pangs of hunger and thirst and the torturing stings of insects, waited for days and days together for a single picture, and been nearly drowned, both figuratively and literally."

This enthusiasm was born in these photographers, for one of them tells how when he was only nine years of age he went out nest-hunting, and coming upon a nest which was new to him, he determined to wait till the bird returned. Hiding himself in the hedge, the little fellow waited patiently, but the bird was long in coming; darkness fell, and sleep soon overtook the young enthusiast. It was only when his people became alarmed at his continued absence, and a search party had been sent out, that the boy was aroused from sleep.

While the Keartons are most desirous that amateur photographers should betake themselves to the fields, they very wisely point out that such photographs as they themselves have obtained are not to be got without a great deal of patience. In order to let the would-be photographer know what he must be willing to endure, one of them says: "Kneel in one position for half an hour and look steadfastly through the keyhole of a door, multiply the time and pain by eleven, and add a complete disappointment, when some idea will be gained of what has happened to my brother and myself over and over again during the last few years."

The Keartons devised many means of getting their camera close up to the nests. One plan was to have the camera enclosed inside a stuffed sheep, with the lens peeping out through a hole in the breast. The operator then hid in a rush-covered tent, whence he could watch for the bird's return, and "pull the trigger" from his hiding-place. At other times the photographer concealed himself and his camera inside an imitation ox, taking the photographs through a hole in the breast of the stuffed animal.

Another prominent *nature* photographer, in quite a different field, is Herr C. G. Schillings, of Germany. It was, indeed, a bold idea to photograph wild animals in perfect freedom. Imagine any man going right among the big wild game of equatorical East Africa and calmly taking their photographs.

Professor Lambert, of Stuttgart, has referred to Schillings' photographs in the following terms: "These pictures are of the greatest importance. In them the wild animals of Africa will live on long after they have been sacrificed to the needs of advancing civilisation."

Some of Schillings' most remarkable photographs were obtained during the night by means of a flash-light, and owing to this fact he has entitled his work *With Flashlight and Rifle*. On one occasion he photographed three full-grown lionesses as they came down to a pool to drink during the night. Imagine a man lying in wait in the dark midnight, hoping some savage beast would come close enough to him to be photographed!

In another photograph a lioness is seen actually springing upon an ox, while a large lion, having allowed the

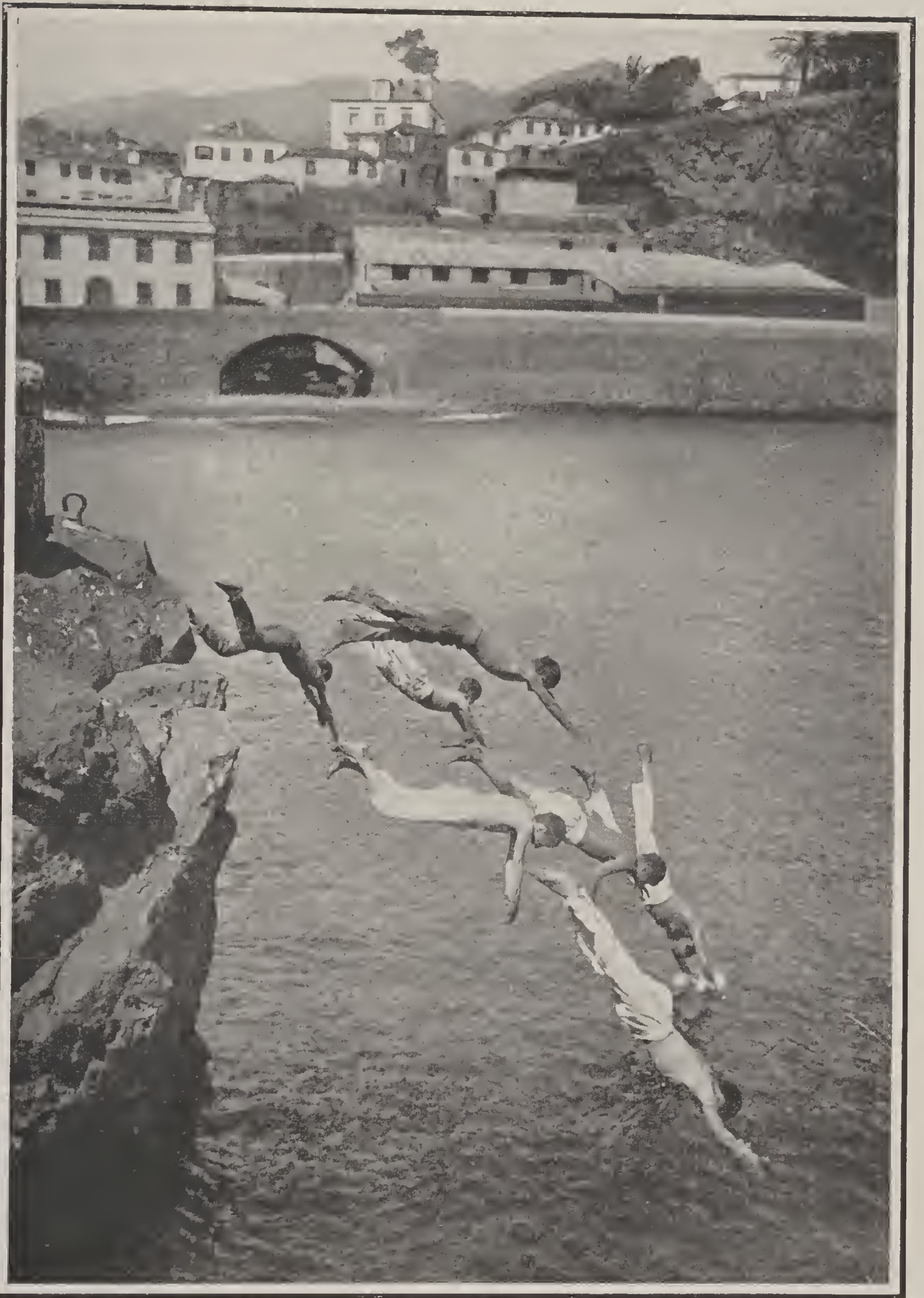


Photo by *Signor T. M. Bianchi, Madeira*

PORTUGUESE DIVING

The whole detail of this living scene was recorded by the great artist, Light, in one five-hundredth part of a second. This exposure was obtained by means of a Thornton-Pickard Focal-plane shutter.

lioness, as is his custom, to make the attack, comes to help to devour the prey. In one photograph a lioness was taken at a distance of only three yards.

On many occasions while Herr Schillings was following some other animal, such as a gazelle, he suddenly found lions and lionesses, within a hundred paces, stealthily approaching him. One can scarcely imagine the nerve-power required to keep cool under such circumstances.

Among Herr Schillings' "sitters" there were huge elephants, rhinoceroses, hippopotamuses, giraffes, zebras, hyænas, etc. These photographs, of animals in perfect freedom at their own home, were not obtained without much experience gained through many disappointments in previous expeditions made by Herr Schillings. This gentleman has the rare combination of being an expert photographer and a fearless hunter.

Some interesting photographs have been taken from balloons, and it is a strange fact that some of the best photographs have been obtained on dismal rainy days. The reason why moisture in the air aids aerial photography is doubtless because it prevents the dust motes from reflecting the sunlight. It is quite impossible to take a photograph from a balloon at a height of four thousand feet because of this reflection from the dust motes.

One well-known aeronaut, the late Rev. James Bacon, received a very strange request from the Russian Government. It was shortly after the tragic incident in the North Sea, on which occasion a British fishing fleet was fired upon by some Russian battleships which were proceeding to the seat of the Russo-Japanese War. The Russians declared that some Japanese torpedo-boats had been seen among the fishing boats, and they were naturally anxious to prove that this was the case, if they possibly could. The Russian Embassy requested the British aeronaut to proceed to the scene of the mishap in his balloon, and while hovering over the waters to take photographs which would show the depths beneath. The idea was to photograph the phantom torpedo-boat which the Russians declared they had sunk. Although it is quite possible to take good snapshots from a balloon of the regions below the sea-level to a considerable depth, it is needless to say the aeronaut did not accept the commission.

When one of the biograph companies undertook to take animated pictures in the New York subway, they took on hand a very difficult task. It is apparent that the light must be very good if one is to take about one thousand photographs in each minute. It would have seemed to the ordinary photographer to be a practical impossibility to produce sufficient light in the underground tunnel to enable such photographs to be taken. The American photographers thought differently. They fitted a large railway truck with hundreds of very powerful electric lamps. They used what are known as mercury vapour lamps; these give forth a rather hideous light, the red rays being absent. This, however, is a splendid photographic light.

The total light produced was equivalent to fifty-four thousand candle-power. It would require between three and four thousand ordinary glow lamps to produce this candle-power, and even then the total light would be very weak photographically when compared with the truck-load of mercury vapour lamps.

The photographs were taken from a moving train, which practically chased one of the regular trains through the tunnel. The powerful light was carried by the second train, and the light was thrown immediately ahead so as to light up the rear of the regular train. The resulting pictures showed the train flying through the tunnel, and then drawing up at one of the stations. Here some passengers were seen alighting, while others entrained. Then off went the train once more. The pictures attracted considerable attention because of the gigantic lighting scheme which was necessary.

If some one were to hand you the photograph of a building, and ask you to calculate the exact position from which the picture had been taken, you might not be willing to undertake the task, but the request would appeal to you as being quite a reasonable problem.

If, however, some one were to hand you a similar photograph and ask you to calculate the day and the hour when the photograph was taken, you would doubtless consider the request as a jest. This seemingly impossible task was undertaken, some years ago, by a mathematician.

The subject was a photograph of one of the American observatories in Nebraska. This photograph was found in one of the old catalogues of the observatory, but it was not known when, nor by whom, the photograph had been taken. Professor Rigge set himself the task of calculating the exact date and hour at which the photograph had been taken.

Fortunately the sunlight had been strong, so that the shadows cast by different parts of the buildings were very marked. By means of these shadows the mathematician was able to calculate the exact position of the sun in the heavens. This was no light task. But as the sun has a twofold motion, and as each motion is independent of each other, a shadow gives us both the time of the day and the day of the year.

Having obtained the exact position of the sun, the professor found that there were two different dates during the year on which the sun was in this particular position. One day was the 2nd of May, and the hour a few minutes past three o'clock in the afternoon. The other possible date was in the month of August. A close examination of the grass and the trees in the photograph decided that the earlier date was the correct one.

Having calculated the exact hour and the day of the year upon which the photograph was taken, how could the particular year be determined? The shadows would be the same each year at the same time, so some other evidence must be appealed to. As the photograph appeared in the observatory catalogue for the year 1894, it was clear that the picture had been taken before that date, but it might have been taken many years earlier. How then could the particular year be discovered?

It so happened that the weather vane of the observatory was distinctly seen in the photograph, and its direction was due north-west. A continuous record of the direction of the wind is kept in the observatory, so it was an easy matter to find out in which year the wind was due north-west at three o'clock on the 2nd of May. It was found that the wind had been due north-west on that day and hour in 1893.

Further evidence could be brought forward by the photograph. Some trees at a distance of three miles were very distinctly seen, and this fact indicated a particularly clear atmosphere. Therefore the barometer must have been high, and the wind must have been steady for several hours. All these conditions exactly agreed with the records for the 2nd of May, 1893, while an examination of the records for the same day in 1894, 1892, 1891, 1890, etc., showed that in none of these years did the necessary conditions prevail.

It was therefore definitely proved that the photograph had been taken at 3 p.m. on the 2nd of May, 1893, the achievement being quite worthy of "Sherlock Holmes." In order to show that the day and hour were correct, a duplicate photograph was taken in the following summer, at 3 p.m. on May 2nd, when every shadow was found to coincide exactly with those in the original photograph.

While a simple photograph is a truthful witness, it is apparent that it is a witness which may be easily tampered with. If a photograph could be used as a witness in a law court, then a criminal might be able to prove an alibi by trickery. It is quite an easy matter to insert one's photograph into a second photograph, and then reproduce it as a complete picture. A criminal might have his photograph inserted into some picture which it could be proved was taken in a distant town on the day and at the hour of the alleged crime. The criminal could not have been at the place of the crime, as the photograph would "prove" him to have been in a distant town.

When an heir to the Crown Prince of Germany was born, there immediately appeared a picture post card with a photograph of the Kaiser with his little grandson in his arms, while the Crown Prince and Princess stood close beside him. The photograph appeared within twenty-four hours of the birth of the future ruler, and before the Kaiser, who was in Norway, had ever seen his little grandson. This "faked" photograph was the subject of an action at law, brought by a photographer who did photograph the royal group later.

Quite a lot of legitimate amusement may be got by "faking" photographs. A man may be shown sitting at a table earnestly playing cards with himself as his opponent. Or, again, quite a natural photograph may be produced of the man having a heated discussion with himself. Faked photographs occasionally appear in our law courts, and it has been repeatedly proved that to issue a faked photograph as genuine is distinctly illegal.

CHAPTER XIX

PHOTOGRAPHING THE STARS

Early daguerreotypes of the moon—The astronomer's camera—A difficulty overcome—Some useful applications of photography—Photographing stars never seen by man—Photographing an extinct star—Discovery of small planets—Photographic discovery of Saturn's ninth satellite—Going round the wrong way—Wonderful maps of the moon—Vast nebulæ that dwarf the solar system—Photography and solar eclipses—Photography and the spectroscope—How we tell what the stars are made of—Some stars approaching us—Discovery of a double star—An amusing incident on the Alps—Photography's important part in astronomy.

PHOTOGRAPHY was in its very infancy when it was suggested to try and obtain pictures of the heavenly bodies. The first photographic studios were just being opened (1840) when Dr. Draper, of New York, succeeded in taking the moon's photograph by the daguerreotype process. These early attempts were very imperfect, but some fair specimens of lunar photographs were shown at the great London Exhibition of 1851. These were also taken by an American.

The first idea was simply to use a telescope as the lens of a camera, and this method continued up till 1870. Why not use an ordinary camera? We may easily obtain a photograph of the full moon in an ordinary camera, but the image will be very small, probably about one-tenth part of an inch. To obtain a larger image we must use a lens having a greater magnifying power.

Suppose, then, that we have a camera fitted with a special *tele-photo* lens, and we try to take a photograph of the full moon. We find that our efforts have met with success, and so we decide to try and photograph some of the distant stars. This time we meet with complete failure, and we find the reason of our failure to be that the stars will not stay in one place long enough to let us get a photograph. As a matter of fact, it is our camera that will not remain in one position; it and we with it are all moving through space. With our faithful moon we are waltzing around the sun. It is the turning motion which bothers us when we try to take a photograph of the heavens. We did not notice this when we took a photograph of the full moon, because the light was so bright that we practically took a snapshot of it. The exposure was only a fraction of a second. We find, however, that so very little light reaches us from some stars, that these ether waves of light require several hours of constant action upon the chemicals on the photographic plate before they can make any impression. Herein lies our difficulty, for during these hours the camera has been turned round in the waltz to quite a different position. Indeed, it has never remained long enough in one position to receive any impression of the star which we were endeavouring to photograph.

How, then, are we to overcome this difficulty? We must keep turning our camera round in the opposite direction to that in which the earth is carrying it, so that the eye of the camera will remain steadily fixed upon the star. Of course, it appears to us as if the stars were moving and we ourselves were stationary, for we have no sensation of movement through space; everything, including our atmosphere, is going with us, and no resistance is offered to our progress.

The large telescopes had already been fitted with clockwork, which kept them moving round at the required speed to counterbalance our movement in the great celestial waltz. The camera could therefore be clamped on to the side of the telescope, so that it too would keep a star in view. A star appears as a mere point of light, so that any movement will be very noticeable. Even the best clockwork may not serve to keep the camera quite steadily on the star for a very long exposure. In this case the observer must watch the star through a small telescope which is moving along with the camera. This telescope is provided with cross-wires in the eyepiece, so that the observer may get the star into a definite position as regards these cross-lines; and if the clockwork tends to take the camera too fast or too slow, he may retard or hasten the clockwork to rectify the amount of such error. In this way excellent photographs have been taken.

It will be of most interest to the reader to know what useful purposes photography has served in the study of the celestial bodies. We are accustomed to hear stars described as of the *first magnitude*, or the *sixth magnitude*, and so on. This is really no description of their relative sizes; it refers to their apparent size. One star might appear larger than another because it happened to be nearer to us. Even the sun and the moon appear to us to be very much the same size, and yet we know that the diameter of the sun is four hundred times greater than that of the moon. Again, one star might appear larger than another because it had a greater luminosity.

We see that the *magnitude* really tells us nothing but the apparent size of one star compared with another, but astronomers have found it convenient to describe the stars in this comparative manner. Stars of the first to the sixth magnitudes are visible to the unaided vision. Those of the seventh magnitude and upwards can only be seen with the aid of telescopes, and may therefore be called *telescopic* stars. As more powerful telescopes were made further ranges of stars were brought to view, till the number of magnitudes was increased to twenty. It is obvious that a question of the personal equation comes in here, for one observer might describe a certain star as belonging to the tenth magnitude, while another observer might say that it should belong to the eleventh magnitude, and so on. Photography can supply a more reliable comparison.

If we expose a photographic plate to a group of stars for five seconds, only the brightest stars will be able to impress their images upon the sensitive plate. A second and similar plate exposed for ten seconds will reveal some of lesser brilliancy, as well as those already seen upon the first plate. A third plate exposed for twenty seconds will reveal more, and so on. If we go on increasing the time of exposure in this manner until we are into hours instead of seconds, we shall find that after we have photographed all the stars visible in the best telescopes, we may still continue adding to the numbers on the photographic plate. We are then photographing stars which have never been seen by mortal man.

Astronomers have reason to believe that some of these stars which we have just been considering are so very far distant from us that the ether waves of light sent out by them take many thousands of years to reach us. This seems almost incredible when one considers the fact that light travels at the enormous speed of nearly two hundred thousand miles per second. Here is a curious thought. We might set up a camera to-day and take a photograph of stars which ceased to send forth light before the Flood. Indeed, it may be that we have photographed stars which disappeared before man ever lived upon this earth. It would not affect this statement even if we granted that man may have been a tenant of this planet for one hundred thousand years.

The largest possible number of stars to be seen by the unaided vision certainly does not exceed five thousand. In one part of the heavens as many as two hundred thousand stars have been carefully mapped out, with the aid of powerful telescopes. In the same area as many as two million stars have been detected by photography.

Picture the astronomer of not so long ago sitting night after night at his telescope hard at work making a map of a certain part of the heavens. What a tedious and difficult task to fill in all these little specks in their proper places. Then picture the present-day astronomer setting his camera in any desired position and in a few hours obtaining an absolutely true chart. Photography accomplishes in a few hours a task which would otherwise require years of patient labour.

The astronomer is keen to note any change among the heavenly bodies, and so he repeatedly compares the heavens with previous charts. When an additional star-like object does appear, he watches it carefully for hours to see whether it is a fixed star or a small planet, known as an asteroid. If he finds that it has any forward motion, then he knows that it is an asteroid. Nowadays, photography is a useful assistant in determining this point. On the negative all fixed stars will appear as little dots, while the small planet will appear as a streak, for it will have made a slow procession across a part of the plate. It will be remembered that the motion we have given to the camera, by clockwork, merely keeps the camera pointing steadily at the stars, so that any movement of the small planet among the stars will be detected.

The physical nature of these asteroids is not known, but it is supposed by some astronomers that they may be fragments of some great planet disintegrated in past ages. The largest of these small planets is about five hundred miles in diameter, or, roughly, fifteen hundred miles in circumference. It would be little more than a whole day-and-night journey to go round one of these asteroids in a non-stop express train. Other asteroids are very much smaller, and may not exceed fifty miles in diameter. Since photography has been called in to assist, there have been some thirty new asteroids discovered every year. As many as three of these small planets have been discovered on one photographic plate. The present total is between five and six hundred, and it is believed that we have now photographed all the asteroids whose diameters exceed fifty miles. Like all other planets, these asteroids are lighted by the sun and are comparatively near to us, while the stars, which are themselves suns, are millions of times farther off.

While we think of those asteroids as very small bodies compared with the great planets, we must not picture them as being of merely meteoric size. Many of them are about the size of Great Britain, and they move around the sun in the space between the four inner planets and the four outer or giant planets.

A century ago we believed that only three of the planets had satellites—faithful attendants like our moon. Now we know of five such systems, and it was photography that discovered two of the new satellites for us.

There is an interesting point in connection with the discovery of one of these two satellites. In 1898 it was announced that a new satellite (Phœbe) had been discovered moving around Saturn. This made the ninth satellite for the mysteriously ringed planet, but the announced discovery was not generally accepted as fact. The only evidence was a photographic plate; there must have been some mistake. All attempts to find this satellite with the best telescopes failed; the beautiful and youthful Phœbe must be a myth, like the great Apollo himself, from one of whose epithets the word *Phœbe* had been coined.

Long before this time one observer believed that he had discovered another planet, to which he gave the name *Vulcan*, but this supposed discovery was never confirmed, although many photographic plates were exposed to that part of the heavens in which Vulcan should have been. The supposed discovery was therefore determined to be an error. When the announcement of Phœbe's discovery was made and astronomers could not find the satellite with their telescopes, one astronomer jocularly suggested that Phœbe had gone off to look for Vulcan. Years went past and nothing more was heard of Phœbe, till an astronomer in another quarter also found this satellite of Saturn upon a photographic plate.

If some amateur astronomer had suggested that the reason why Phœbe could not be caught by the astronomer's telescope was that the satellite was moving around Saturn in the opposite direction to all other satellites, it would, no doubt, have caused amusement in scientific circles. Such an idea would certainly seem absurd, and yet this very strange fact has actually been discovered by astronomers. Phœbe moves round Saturn in a retrograde direction. Ultimately the satellite was caught by the telescope, but its luminosity is so feeble that there are probably only three or four telescopes existing powerful enough to detect it.

Excellent photographs have been taken of the moon. At first it was usual to photograph the whole moon, but better results have been obtained by taking larger photographs of different parts of our satellite. Recent photographs seem to indicate that the moon is not yet quite dead; that there is still volcanic activity. One eminent astronomer believes that there is vegetation on the moon.

By measuring the shadows cast by the mountains of the moon, it has been possible to calculate the height of these mountains, some of which appear to be covered with snow. Imagine making a complete map of a body which is distant two hundred and thirty-eight thousand miles from us! Yet the maps of the moon which photography has enabled us to make contain every hill or valley that is one mile long and half a mile across.

We can only photograph one side of the moon, for she never turns round to let us see what the other side is like. The moon therefore performs a true waltz with our earth around the sun. Our earth, on the other hand, keeps continually turning around on its own account during the waltz.

Another important part played by photography in our study of the heavenly bodies has been in connection with the sun, and more especially at times when our faithful moon has come between us and the sun, producing a total solar eclipse.

The red flames or *prominences* seen during a total eclipse were proved to be appendages of the sun, for successive photographs showed the moon covering and uncovering these in her grand march past the sun. An idea had also existed that the beautiful corona seen around the disc of the moon at the time of total solar eclipse was an atmospheric effect, but two photographs of the corona taken almost simultaneously from two places many hundreds of miles distant from one another proved conclusively that the corona had no connection with any interference of our atmosphere, but was an effect occurring at the sun.

Photography has been of great service to astronomers in studying the *nebulæ*, which had previously been a puzzle. These nebulæ looked like far-distant clouds, or dull patches of light, and, indeed, were sometimes liable to be mistaken for comets. Photography discovered vast nebulæ which had never been detected by the most powerful telescopes.

These nebulæ have turned out to be great masses of incandescent gas. It has been impossible to say how far these vast bodies are distant from the earth, but there is evidence that they are at least as far off as the stars. Our whole *solar system* is a mere speck in the universe when compared with a great nebula. Each of these vast masses of incandescent gas may, in ages to come, be transformed into a star. We believe that every star commenced as a nebula. Who can say but some day, when our present photographs of nebulæ become "ancient records," the astronomers of ages to come may be able to point to these "old charts" as proof of the birth of some star known to them; the nebula in our photograph being the embryo or beginning of their star.

When we consider our earth to be a mere speck compared with the sun, and when we think of the whole solar system as a mere dot compared with a great nebula, we become lost in wonderment. When we think of all the activity upon this earth, and when we consider the exquisite design in the tiny microscopic shells (illustration p. 216), we find it very difficult to place our whole world within a mere dot in the universe. It is none the less true that if some of the neighbouring planets were inhabited by intelligent beings, their astronomers would fail to discover our world with the best of telescopes. Indeed, unless it so happened that these inhabitants of another planet had acquired the art of photography and applied it to astronomy, they would never know of the presence of our planet in the universe.

Perhaps the most interesting application of photography to astronomy is in connection with the spectroscope. While we find many of the sciences co-related, one would

Photos by *Arthur E. Smith, London*

A TELEPHOTOGRAPH

The upper illustration is an ordinary photograph showing St. Alban's Abbey in the distance. The lower illustration is a telephotograph taken from the very same position, one mile distant from the Abbey. The little frame in the upper illustration marks off the exact portion of that picture taken in by the telephoto lens in the lower illustration. (See chap. xviii.)

have thought that astronomy and chemistry must for ever stand apart. We cannot hope to get to the stars to find out their chemical composition, but the spectroscope has enabled us to find out the different elements present in the sun and other stars.

In those earlier chapters which dealt with the subject of colour photography we considered the effect produced by passing light through a triangular glass prism. We saw that white light was analysed or split up into a spectrum of beautiful colours, commencing with red at one end and finishing with violet at the other end. In order to make the resulting spectrum as sharp and defined as possible, the light is passed through a narrow slot before it reaches the prism. In this way the overlapping of the bands of different colours is prevented, and we have what is called a *pure spectrum.*

A simple spectroscope is therefore merely a glass prism and a shutter with a slot in it. Sometimes the shutter is mounted in a brass tube, and an arrangement made whereby the width of the slot may be altered at will. Then comes the glass prism, and another brass tube with an eyepiece, which is practically a small telescope to magnify the image of the spectrum.

If our subject was the spectroscope, and not photography, we should want several chapters to deal with the subject. We must content ourselves with a few details, such as are necessary to a proper understanding of the part photography plays in connection with spectroscopy.

Before we can examine any substance by means of the spectroscope, the substance under examination must be sending out light. The sun and the stars are therefore suitable objects for examination: but how are we to know what the different spectra mean? Suppose we make a few simple experiments in the laboratory before attempting to photograph the spectra of the different stars.

We wish to examine a piece of iron by the spectroscope; we must make it white-hot. On looking at it through the spectroscope we see a simple continuous spectrum, such as is got from white light. We try another solid body, and the result is just the same. Indeed, we find that all solid or liquid bodies, when made to incandesce, give us a simple *continuous spectrum.* How, then, are we going to learn anything from the spectroscope?

First let us see what appearance a burning or incandescent gas has in the spectroscope. We burn a piece of sodium in a hot flame, say that of a bunsen burner. We at once see a very bright line in the yellow band of the spectrum. This bright yellow line always appears in that position when sodium is in the form of an incandescent gas. Hydrogen, when incandescent, gives a bright line in the red and a bright line in the blue. There are other lines seen with good apparatus, but these two lines are always particularly prominent. And so we find that every incandescent gas has definite bright lines.

Suppose we are examining a sodium flame, and we see in the spectroscope a bright line in the yellow. While we are looking at this, some one makes a white light shine through the flame, by placing a white-hot solid body behind it. We immediately see a dark line in the yellow band in the place of the former bright line. The sodium flame has absorbed certain rays from the white light passing through it, and so cut them off, leaving a blank in their place in the resulting spectrum. We may therefore detect sodium by this dark line. This is what we have to do when examining the spectra of the heavenly bodies. The light from the distant star is passed through a spectroscope, and a record of the spectrum is made to impress itself upon a photographic plate. We find a great number of dark lines; the positions of these are carefully noted and compared with the different spectra which we can produce in the laboratory in the manner already indicated. A careful examination of a photograph of the spectrum of the sun shows us that hydrogen, sodium, iron, copper, nickel, zinc, etc., all exist in that great body which is ninety-three millions of miles distant from us. We are not to think of copper mines, etc., in the sun; what the spectroscope shows is that all these substances exist in the sun in a gaseous state.

To-day many observatories are taking photographic records of the spectra of the different heavenly bodies. These records should be of great interest in the centuries to come. Future astronomers may compare our records with the spectra then obtainable, and thus note any alteration in the condition of the stars.

Even in our own time, many interesting facts have been discovered by very carefully comparing the lines obtained in different photographs of the spectra of some distant stars. The lines of hydrogen, for instance, should appear in all photographs in exactly the same position in the spectrum, no matter whether it be a distant star or a laboratory experiment which is being photographed. It was found, however, that there was a slight difference in the position of these lines in certain stars. Take, for instance, the star Sirius, the brightest in the heavens, and perhaps better known to some as the Dog Star. It was found that the lines representing hydrogen were very slightly nearer the red end of the spectrum than on the records made of other stars, and also of hydrogen burning in the laboratory. What could this mean?

Have you ever been standing on a wayside railway platform when an express train was about to run through the station? The whistle of the engine seems to rise in pitch as the train rushes towards you, and falls again to a lower note as the train passes away. Indeed, it has quite the effect of a syren, and yet we know that the whistle is sounding only one definite note. The whistle is setting up one definite rate of air vibration all the time; but as the train rushes towards you these air waves arrive, one after the other, quicker than they would if the engine was standing in one position. Hence a higher pitch of note. Imagine the whistle giving a definite number of blows to the atmosphere in a certain space of time. We then picture the sound wave set up by the first blow to be travelling towards us; but the engine darts forward as it gives the second blow. It is just as though the engine made up very slightly upon the first sound wave before it dealt the second blow, so that the air waves follow each other closer than they would otherwise do. They come tumbling against your ear in quicker succession than they would do if the engine remained standing while it dealt out the blows. On the other hand, when the engine is rushing away from you, the vibrations or pulses are a little farther apart, the engine moving farther and farther away at each blow.

Keeping this analogy before us, we note that the position of the dark lines really indicates the pitch of the different rays of light. If the rate of vibration be increased, the dark line will move nearer the violet end of the spectrum; that is, "up the scale." If the rate of vibration be decreased, the line will move down the scale towards the red or lower end of the spectrum. Looking at the record of Sirius, we find the displacement is so small that it requires delicate apparatus to measure it. The displacement is towards the red end; the Dog Star is therefore receding from us. The amount of displacement in the spectrum indicates the rate at which this far-distant star is travelling. In the case of Sirius we find it is moving away from us about twenty miles every second. Other stars are receding at rates of from ten to thirty miles per second. One might be rather alarmed to learn that the spectrum photographs of some stars prove that they are approaching us at somewhat similar speeds. It will be apparent that there is no cause for panic when we consider that the nearest star to us is many billions of miles away, while some stars are distant thousands of billions of miles from our little globe.

It is surely a very remarkable achievement to be able to tell whether a body, distant billions of miles from us, is approaching or receding from our earth! Why, if one stands on a long, straight road, it is difficult to tell whether a distant tramway car is approaching or receding from us!

There is another interesting astronomical discovery due to photography which I shall merely mention. Many spectrum photographs had been taken of one of the stars in the constellation known as *The Great Bear*. On some of these photographs it was found that one of the prominent lines in the spectrum was sometimes double, while in other photographs it was single. It was proved that this star must in reality be two separate bodies very close to each other. Photography therefore discovered the double star, which up till then passed itself off as a single star to all observers. The line was single in some photographs, because at the time of taking such photographs the one star, revolving round the other, hid its twin brother from the eye of the camera.

There is an amusing incident related by Sir William Abney in connection with spectrum photography. On one occasion this learned scientist was taking some photographs of the sun's spectrum from the summit of one of the Swiss Alps. He had travelled from England to get a clear atmosphere, and also to get a little nearer to the sun by climbing a high mountain. Of course, the actual difference in distance would make no appreciable difference, but by climbing to this height he would have less atmosphere between the sun and his camera-lens, which would be a distinct advantage.

The particular object of study was to determine whether a certain group of lines in the photographic spectrum beyond the visible part might not be due to a hydro-carbon vapour.

While Sir William Abney was arranging his instruments, an American gentleman came upon the scene and watched the scientist with patient interest. After one hour of silent watching the American said, "I guess, sir, you've got a photograph behind that." To this the scientist agreed. The American next exclaimed, "Well, sir, what are you doing with the sun?" It flashed into the mind of the scientist that here was an opportunity of having some fun. Sodium, of which soda is one combination, had already been found in the spectrum of the sun; alcohol and brandy might be classed as carbohydrates along with the hydro-carbon vapour for which he was searching. With these thoughts in his mind the scientist gravely replied, "Sir, we have already found soda in the sun, and now I am trying to find the brandy." The American made no further remark; he hurried down to Zermatt, and informed the people in the hotel that he had encountered a lunatic Englishman on the mountain. "The poor fellow was trying to get a brandy and soda from the sun."

In closing this chapter it may be of interest to add that one observatory (Harvard College) has taken as many as six thousand stellar photographs in one year. This indicates the important part which photography plays in connection with modern astronomy.

CHAPTER XX

PHOTOGRAPHY AND SCIENCE

Photographing sound waves—Photographs of flying bullets—Collision between two drops of water—The splash of a drop of water—The breaking of a soap-bubble—Ripple photography—A falling cat—Crossing waves—Photographing through Nature's lenses—Fish-eye photography—Far-distant earthquakes photographically recorded—Other spot-light photographs—Is there such a thing as dark lightning?—Cloud photography.

TO speak of photographing sound waves in the air will doubtless seem quite ridiculous to the ordinary reader, and yet several scientists have accomplished this wonderful feat.

I remember seeing quite a large collection of photographs of air disturbances which were taken by H. Stanley Allen, at Lord Blythswood's laboratory, in 1901. The method of taking these photographs was very ingenious, and the results were admirable from a scientific point of view, although the man-in-the-street would have failed to see their value; there was nothing picturesque about them.

The general reader would appreciate more readily the photographs taken by Professor C. V. Boys, where air waves are distinctly seen around flying bullets. A collection of these photographs is to be found in the Physics Department of the South Kensington Museum (London). The general effect in a photograph of the flying bullet is very much the same as that of a steamer ploughing its way through the sea. Both the waves which spread out from the bow, and the disturbance or "wake" which follows in the trail of the steamer, are well represented in some photographs of a simple flying bullet. In other photographs the air waves are seen reflected from a sheet of metal placed in their path, and their behaviour is exactly like waves in water. But how did Professor Boys manage to photograph flying bullets?

To attempt to photograph a flying bullet by means of the very best of instantaneous shutters would be absolutely useless. We may take a snapshot of a train going at an express speed of sixty miles per hour, but the bullet is travelling at a speed of one thousand four hundred miles per hour. A momentary flare of flash-light powder is good enough to obtain a picture of a crowd of people assembled together, but quite useless in the case of a flying bullet. During the sudden flash of light the bullet would have passed with lightning speed across the area covered by the photographic plate. It is obvious that the illumination must be very short indeed before we can catch the image of a flying bullet. It goes so fast that we are unable to see it in its flight. Where are we to get an illumination sudden enough for the purpose?

An electric spark will give an illumination of the shortest possible duration. It has been calculated that some electric sparks occupy less than the one millionth part of a second. But all electric sparks are not of the same duration. Indeed, Professor Boys found that the first kind of electric sparks which he tried were far too slow to photograph the bullet shot from a magazine rifle. During the fraction of a second in which the spark existed, the bullet had travelled half an inch across his photographic plate. By adjusting the electric apparatus he was able to get sparks of so short duration that the flying bullets appeared in the photographs as though they were quite stationary in mid-air. But how is the photographer to snap his picture at the right moment? He wishes to have the image of the bullet right on the centre of his photographic plate, but the whole time during which the bullet is within the compass of his camera cannot exceed the one two-hundredth part of a second. It is quite evident that the photographer cannot "press the button" at the required moment. The bullet itself must operate the electric spark.

We need not trouble with the detail of the electrical apparatus further than to note how the spark is timed. A spark-gap is arranged in such a manner that a spark occurring at this point will illuminate the whole area covered by the camera. An electric charge is waiting ready to spark across this gap, but it cannot do so because of another small gap in one of the connecting wires. The moment that this second gap is bridged over by a piece of metal the discharge takes place, causing a spark at the desired point. Let the bullet itself be the piece of metal to bridge the gap in the connecting wire. This wire-gap may be arranged so that it forms the bull's-eye to be aimed at. The instant that the bullet fills this gap the electric discharge takes place across the illuminating spark-gap, and this all happens so very suddenly that a good snapshot photograph is obtained of the flying bullet.

An interesting series of such photographs was taken of a bullet piercing a sheet of plate-glass. A photograph of the bullet was taken just entering the glass, and this showed a cloud of glass dust thrown backwards in the opposite direction to that in which the bullet was travelling. Another photograph of the bullet was taken after it had reached a distance of five inches beyond the sheet of glass. This showed the bullet completely enveloped in a thick cluster of glass dust, giving the bullet the appearance of a long brush; the five-inch space between the bullet and the hole in the plate-glass being also filled with a mass of glass dust.

Another photograph which Professor Boys took when the missile had reached a distance of fifteen inches beyond the glass showed the bullet quite clear of the glass dust, but close to the bullet there was a single piece of glass, which, no doubt, was the piece immediately struck and punched out by the bullet. This piece of glass is seen to be travelling along by itself at a speed practically equal to that of the bullet. This small piece of glass is seen to be causing air waves on its own account. The air waves in all these photographs might be mistaken by a casual observer for cracks on the negative.

These experiments ingeniously carried out by Professor Boys were suggested by some similar experiments made by Professor E. Mach, of Prague. The method of obtaining the photographs was considerably modified by Professor Boys.

Professor Boys also took some interesting electric-spark photographs of a fine column of water falling from a jet. At first the water looked like a rope or cylinder, and then it began to bulge out at intervals, leaving a narrow neck between each pair of beads. At last these beads were seen to separate into little drops quite separate from one another. The same scientist photographed two drops of water in the act of bouncing against one another. The drops were flattened as they met, and behaved just as though they were india-rubber balls.

Professor Worthington took a series of electric-spark photographs of a drop of water falling into milk. One photograph was taken just as the drop of water struck the surface of the milk, and this showed quite a cavity in the surface. Then one of the succeeding photographs showed quite a tall pillar of milk in the place where an instant before there was a hole. This effect was caused by the milk rushing in to fill the cavity, and in so doing the high pillar was momentarily formed. But for the testimony of the photographic plate we could not know that this strange result really happened during the splash of a drop of water.

Lord Rayleigh took some very interesting electric-spark photographs of a soap-bubble in the act of breaking. In these photographs the retreating edge of the bubble, as it broke, is seen with all the accuracy and sharpness of a stationary object.

Some interesting facts concerning ripples on the surface of liquids were determined by Dr. J. H. Vincent, by means of electric-spark photography. This scientist caused different sets of ripples to be set up simultaneously on the surface of mercury, by means of two points attached to vibrating tuning-forks. The electric-spark photographs showed many interesting phenomena which could not be seen by the eye, owing to the rapidity with which they occurred.

Some of the phenomena met with in the study of Sound and Light, such as reflection, interference, and refraction, have been well illustrated by this means. Some of these ripple photographs may be seen in the Physics Department of the South Kensington Museum (London).

I have already referred, in an earlier chapter, to the electric-spark photographs taken of a flying insect. It is interesting to note that another experimenter made a series of such photographs of a cat falling from a height. The idea was to show how a cat was able to turn round in the air and land on her feet upon the ground. I understand that from a pictorial point of view the photographs were not very successful; the reason given being that the subjects did not care for this form of scientific investigation. No doubt the experimenter would have difficulty in obtaining sufficient illumination to get all the detail of a falling cat.

In the illustrations facing page 298 we have two very interesting photographs of wave effects, taken by Dr. Vaughan Cornish. The upper illustration shows two waves crossing each other almost at right angles and each continuing on its own way. Dr. Cornish has kindly given me the following particulars:—

"The intention of the photograph is to illustrate a fundamental property of waves, namely, their interpenetration and subsequent continuance each in its original course. It required six months' waiting to obtain it. The photograph was taken with a No. 1 binocular camera, pointed downwards, the centre of the picture being about twelve feet distant. The photographer stood in the water, which had a depth of only two or three inches, upon a sandy shoal. The occasion was low water of a spring tide, and the locality the sandy shore opposite Branksome Chine, near Bournemouth (England). The weather was calm, and the ordinary waves, coming in from the offing and breaking some distance out, gave rise to small solitary waves foaming at the front.

"At first the solitary wave leaves the foam behind, but as the water becomes shallower, and the speed of the wave is thereby reduced, the foam which it makes travels with it and becomes a roll of opaque white froth which outlines the wave-front with great distinctness, and gives the photographer his opportunity.

"At the moment when this photograph was taken a 'solitary' wave, deflected from the shore and travelling seawards over the sandy shoal, met the next incoming wave at a spot which was brought to the centre of the camera's field of view. Below this, in the photograph, the waves had previously met and passed through each other, each pursuing its original course. The line of momentary interference is recorded by an irregular band of foam. On either side of this the waves are seen to be pursuing each its original course. The increased amplitude of the momentarily combined wave is clearly shown at the point of intersection."

I may remark that this photograph attracted a good deal of attention at the St. Louis Exhibition (U.S.A.), and it was one of the photographs selected by the Royal

By permission of *Dr. Vaughan Cornish*

PHOTOGRAPHY OF WAVES

The upper illustration shows two waves crossing each other, and each continuing on its own way. It took six months' waiting to obtain this photograph. The lower photograph shows sand waves produced by currents. (See chap. xx.)

Commission for the souvenir volume of the British Exhibit.[1]

The lower illustration (p. 298) is a photograph taken in the Dovey Estuary, North Wales, and shows sand waves produced by currents. This photograph is of scientific value, and by request Dr. Vaughan Cornish has given a copy of it for preservation at the Geographical Society of Berlin. The full title given to the photograph is "Current mark and tidal sand waves."

When considering *Nature's camera*, I incidentally remarked that the eye of a particular species of beetle produced as many as twenty-five thousand images of the object which it was viewing. The experimental proof of this is very difficult to carry out. It is indeed remarkable that any one can dissect the head of a beetle so as to remove the eye without injury. The retina and the dark pigment interlining the eye have to be very carefully removed with a fine camel-hair brush, and the miniature transparent lens has to be placed in proper position in front of the objective of a powerful microscope.

Having got the tiny lens, the microscope, and the camera in position, the scientist then takes a glass transparency, say a photograph of a man, and he places this

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[1] The binocular camera mentioned by Dr. Cornish in connection with this photograph of crossing waves is rather like an opera glass in appearance. One half of the instrument is a camera and the other half is practically one eyepiece of an opera glass. The photographer holds the instrument up to his eyes, as he would hold an opera glass, and this he does while he is in the act of taking the instantaneous photograph. In this way the photographer was able to bring the image of the crossing waves fairly on to the centre of his sensitive film.

so that a strong image of it is reflected on to the tiny lens, or in other words, the eye of the beetle. The microscope enlarges the manifold image formed by the insect's eye, and a photograph is taken of the enlarged image produced by the microscope. It will be obvious that it would be quite impossible to observe the manifold image produced by the beetle's eye except with a microscope, as the whole area of the eye is a mere speck, and in this space there are twenty-five thousand distinct images. Of course, one cannot hope to make the whole of these images simultaneously visible in one photo-micrograph, the necessary magnification being so great that only a portion of the whole can be brought within the microscope lens at one time. In a photo-micrograph measuring one and three-quarter inches by two and a half inches I have counted as many as one hundred distinct images, each image being an exact duplicate of the other.

An Austrian professor, anxious to see what an insect really sees, arranged his apparatus in a similar manner to that just described, but instead of throwing the image of a photograph upon the insect's eye, he allowed an image of the view obtained from his window to fall directly on the little lens. In this experiment the eye of a firefly was used so that a larger picture might be produced, not by any increase in the size of the tiny eye, but because this insect's eye does not produce manifold images, as in the previous case. Quite a good photograph of the window, with a church in the distance, was obtained by this means.

With such very small lenses as those from the eye of a beetle or a firefly it is necessary to take the photographs through a microscope, but experiments have been made with some of Nature's larger lenses, allowing the microscope to be dispensed with. The crystalline lens taken from the eye of a freshly killed bullock has been used in place of the ordinary camera lens. Very great care is required in handling this natural lens, but the results obtained, in some cases, have been excellent.

A totally different series of experiments was made by Professor Wood (U.S.A.), and described by him in the *Philosophical Magazine* of August, 1906, under the title of "Fish Eye Views."

In the illustrations opposite page 254 we saw how light was bent in passing from the air into water. Imagine the penny in these photographs to be the eye of a fish which is swimming in the basin. It is obvious that the fish would have a very wide range of vision, the light being bent over the top of the basin at every point around its circumference. Therefore a fish placed at the centre of a small pond of clear water must have a very wide view of the objects surrounding the pond.

It is difficult to make personal experiments; our eyes are not adapted to distinct vision under water. It is well known, however, that if one looks upwards from beneath still water one sees the sky compressed into a comparatively small circle of light, the centre of which is always immediately above the observer. It just looks as if the whole pond were covered with a dark roof, with a circular window in its centre. As already stated, it is difficult to distinguish any objects that are out of the water.

It occurred to Professor Wood that an excellent notion of how we appear to the fishes could be obtained by immersing a camera in water and photographing the circle of light above it.

The apparatus was constructed out of a lard pail and a short focus lens provided with a diaphragm having a very small aperture in it. The lens and its diaphragm were fitted into a metal disc, which rested on a metal rim soldered around the inside of the pail, about midway between the bottom and the mouth of the pail. The lower half of the pail was therefore to act as the camera or imitation fish's eye. This part of the pail was filled with clear water after the photographic plate had been placed in position on the bottom of the pail. This operation was necessarily performed in a dark room. Then the upper part of the pail was also filled with water, so that this part of the pail represented a miniature pond. The lens of the submerged camera was covered with a metal cap, keeping the dark chamber light-proof. This shutter was provided with a handle on the outside of the pail, enabling the shutter to be opened and closed at will.

This miniature pond with its submerged camera was then placed upon the ground, and a number of extremely interesting photographs were obtained with this device. A number of men standing around the miniature pond were seen in the photograph in a somewhat distorted condition, and this must be the idea a fish gets of us when we look into the small pond or river in which he is swimming.

By modifying the apparatus so that it could be held in a horizontal position, one could make the camera " look " along instead of upwards. In this position the camera takes the place of the eye of a fish looking out through the glass sides of an aquarium. Some very curious photographs were taken in this manner. Again, the fish has a very wide range of view.

If a straight row of nine men were to stand close up to the side of the glass aquarium, the fish would see the whole row of them, but not in a straight line. They would appear to be standing in a large semicircle, with their backs to the centre of the circle. The men at the ends of the row would appear to be away out about the centre of the room instead of being in a straight line with the fish's domain.

It will be understood that Professor Wood was not experimenting with the eye of a fish, but with a photographic apparatus made to imitate the fish's eye. In the experiments described immediately before these, the actual eyes of beetles, etc., were used to focus the images for the camera.

Photography is of great service to science quite apart from the pictorial aspect. The movements of a spot of light may record themselves upon a photographic paper, and by keeping a sensitised paper ribbon in regular processional motion, a spot of light falling upon it will leave a continuous record of all its movements.

One interesting application of this fact is in automatically recording far-distant earthquakes. It may seem quite ridiculous to attempt to record the altogether imperceptible tremors caused in Great Britain by earthquakes occurring in India, Siberia, or Japan. We are totally unconscious of any such tremors, but our photographic paper will inform us of their occurrence.

In the British Observatory we dig a deep pit until we get down twenty or thirty feet below the surface. We then erect a solid pier or pillar of masonry upon this deep foundation. The top of this pier pops up in the observatory, through a hole in the floor, and is used as a small table upon which the earthquake apparatus, or *seismograph*, stands. The instrument is therefore quite safe from all local surface disturbances.

The instrument consists of a long boom, which is so very light and so delicately poised that it will move with the very slightest tremor of the earth. This boom, which is made of aluminium, will merely oscillate from left to right, the total distance of its to-and-fro vibration being very small. It must be obvious that there is no use in attempting to record the movements of this boom by attaching a pen or other marker to it. Any such arrangement would immediately arrest the movement of the boom. It is here that photography steps in to aid the scientist.

The end of the boom carries a very light plate or shutter of aluminium, in the centre of which is a longitudinal slot, while there is above this a lateral slot in the mahogany case which encloses the apparatus. The light of a lamp passing through the intersection of these slots causes a spot of light to fall upon the ribbon of photographic paper, which is kept in continuous and regular motion by clockwork. When the boom is at rest the spot of light makes a black line along the centre of the paper ribbon, while some light gets past the edges of the shutter and makes a black border on either edge of the ribbon. The very slightest movement of the earth causes the boom to vibrate, thus making the centre line wavy and the outer edges irregular, as shown in the accompanying illustration (Fig. D).

This is a reproduction of a photographic record taken in the Coats' Observatory at Paisley (Scotland), and the earthquake, which directly moved the instrument occurred in far-distant Shemakha (Russia).

While the photographic record shows the hour and the duration of the earthquake, it cannot give any indication of the part of the world in which the disturbance has occurred. The earthquake may be recorded here several days previous to any information reaching us as to its whereabouts, especially if the disturbance is in some out-of-the-world place, where all means of telegraphic communication may have broken down.

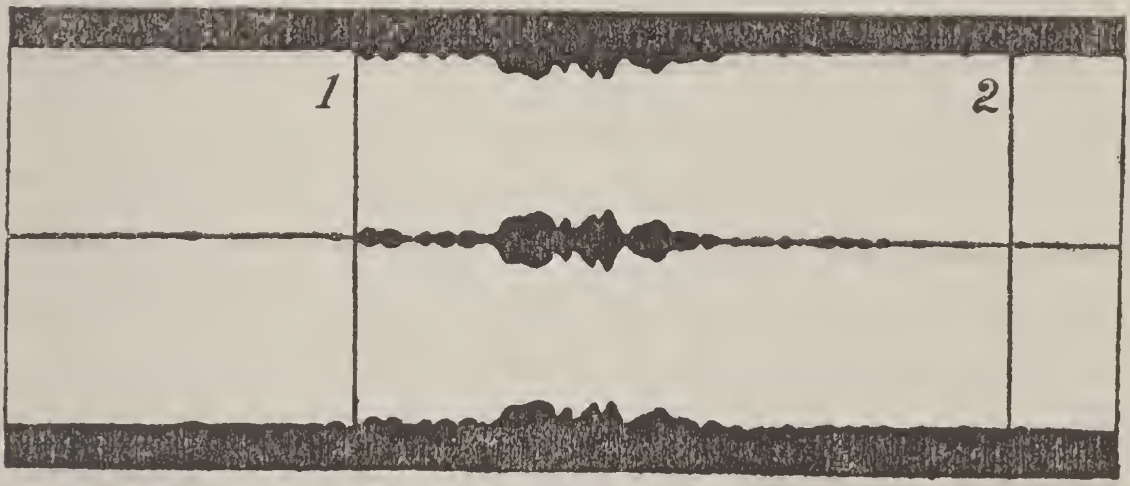


Fig. D

In those observatories where magnetic observations are taken it used to be a very laborious task to note the variations in the directions of the earth's magnetism. A large magnet, measuring about two feet in length, if suspended by a long silk thread, will not point steadily to the magnetic north pole of the earth all day long. It will move slightly to the west between eight o'clock in the morning and two o'clock in the afternoon, and then slowly return eastwards. During the night there is practically no movement. As the total movement from west to east is only about the thirtieth part of an inch at the end of a magnet measuring two feet, it is obvious that it will not concern the mariner. There is, however, a scientific interest attached to these small variations, which are irregular. During some years the average amount of movement is double that of other years. It is always greater in summer than in winter.

The reading of the exact position of the long magnet was a tedious and a delicate task, which had to be performed twelve times every day. Photography stepped in and relieved the observer of his arduous duty. A small mirror attached to the magnet reflects a beam of light directed upon it, and thus throws a spot of light upon a photographic paper. This band of sensitised paper is moved by clockwork, just as in the earthquake apparatus, so that it keeps a continuous record, marked off in hours, of the position of the magnet. The observer therefore obtains a photographic chart showing exactly how far the magnet has wandered from the magnetic north pole.

The photographic spot of light serves the scientist in very many different ways, but the two cases just described will give the reader an idea of this kind of work.

Two Austrian inventors have used a spot of light to write down telegraph messages in ordinary writing upon a sheet of photographic paper. The one great advantage is that the pencil of light may be made to move very rapidly, so that an extraordinarily high speed has been attained. The spot of light is reflected by a little mirror, the movements of which are controlled by the electric current. The spot of light dances about on the sensitised paper, reminding one of the fairy light "Tinker-Bell," in J. M. Barrie's *Peter Pan.*

All the photographic records of the movements of a spot of light are made upon a bromide emulsion paper, and therefore the record is not visible until the paper is chemically developed. In the case of this high-speed telegraph, the apparatus automatically develops the record, so that the telegram is complete when taken from the machine.

In the lower illustration, facing page 308, we see the photograph of an apparent *dark* flash of lightning, and in the legend beneath this illustration I have asked the question—"Is there such a thing as dark lightning?" Scientists could not definitely answer this question at one time, but Dr. W. J. S. Lockyer, of the Solar Physics Observatory (London), has helped to make matters quite clear.

It had been suggested by one writer that the apparent dark flash was produced in the following way. A bright flash having occurred and made an impression upon the photographic plate, another flash follows sufficiently near to the first to illuminate the plate, whereupon the first image will appear dark instead of bright, when the plate is developed.

Dr. Lockyer secured photographs of quite a variety of dark flashes of lightning, and he then proceeded to imitate the results by means of electric discharges in the laboratory.

If we look carefully at the dark flash in the photograph, we shall see that there is a bright core along the centre of the dark flash. Dr. Lockyer was able to produce the same effect by means of electric sparks in the laboratory. His experiments quite confirmed the suggested theory of the dark flashes being due to a second illumination of the plate.

Taking first of all a photograph of a single spark, he developed the plate and found that it represented a bright flash. Repeating the experiment, but leaving the sensitive plate still in the camera, he moved his sparking apparatus very slightly, so that the image of a second spark would fall clear of the first impression. He then caused two sparks to pass in succession, and again four sparks on another part of the plate. The first and second sparks were found to be dark flashes with bright cores, just like the dark lightning in our illustration. The last spark alone appeared as a bright flash. By varying the intensity of the sparks, and that of the illuminated background, it was found possible to produce any combination of bright and dark flashes.

It is therefore quite clear that there is no such thing as dark lightning in nature. Every lightning discharge, if photographed and immediately protected from a second flash, will show a bright flash upon development. The dark flash is only seen upon a photographic plate which has been illuminated after the first impression was made. The apparent dark flash is therefore due to some chemical action which takes place in the photographic film.

Immediately above the photograph of the dark light-

By permission of *Dr. W. J. S. Lockyer,*
Solar Physics Observatory

A Cloud and Dark Lightning

The upper illustration is a study of the formation of a cloud. The lower illustration shows an apparent *dark* flash of lightning. Is there such a thing as dark lightning?
(See chap. xx.)

ning is a beautiful photograph of a cumulus cloud. Cloud photographs are taken for two quite different purposes. The object in this case has been to show the formation of the cloud. It is most interesting to have a series of photographs of a cloud, taken at intervals of a minute between each successive picture. In this way one can see exactly how the cloud changes from one shape to another totally different formation.

The second object in cloud photography is to secure cloud negatives which may be used along with other photographs. For instance, one may have a good landscape photograph, but the sky has nothing of interest in it. If one prints in some clouds from a suitable negative, the general effect of the landscape is greatly enhanced.

We have already seen, in some of the other chapters, many ways in which photography aids the scientist. Not only in the study of the invisible part of the spectrum, and other invisible rays such as those emitted by radium and other radio-active bodies, but also in a study of bacteria and other objects far below the range of vision. In another chapter we saw how photography aided the astronomer, and so on. With what has been added in this chapter it must be clear that photography plays a very important part in scientific research.

CHAPTER XXI

A CAMERA WITHOUT A LENS, &c.

The pinhole camera—The disadvantages of lensless photography—Why we use lenses in the camera—The making of photographic lenses—Some curious points about lenses—Wherein the expense lies—Lenses for different purposes—What determines the focus of a lens?—Early suggestion of a portrait lens—How the lens bends the rays of light—Is the obtaining of a good lens a matter of chance?—How the form of a lens is first determined.

AFTER the reader has examined the illustrations, shown facing page 316, and when he learns that these beautiful pictures were taken through a simple pinhole, he may be inclined to ask why we should bother about using a lens at all.

It is certainly remarkable that such excellent results may be obtained, with no apparatus other than a dark box with a pinhole aperture in it. It will be obvious, however, that there must be some advantages to be gained by the use of lenses, otherwise the photographer would not pay anything from a guinea to one hundred and fifty guineas for a good lens.

Let us first of all see wherein lie the disadvantages of a camera without a lens. We cannot say anything against lack of definition in the two illustrations, but if we were to photograph some large object from a short distance, we should then find a want of sharpness about the picture. Before we could have a pinhole that would focus with perfect sharpness, the hole would require to be so small that it would allow only one ray of light from each point of the object to enter the camera. And the material in which this ideally small hole is to be made must have no thickness whatever. Neither of these conditions can be fulfilled, but by drilling a very small hole in a sheet of very thin brass or tinfoil very beautiful pictures may be produced. This fact is admirably borne out by the two photographs reproduced in the illustration. These photographs were taken by the Rev. J. B. Thomson, of Greenock, who is an authority on the subject of pinhole photography.

I think that, as far as landscapes are concerned, no one will find fault with the productions of lensless photography. Indeed, a lens sometimes produces an unreal effect in a photograph by giving too good a focus. In other words, the lens of the camera may bring the rays of light to a sharper focus than the crystalline lenses of our eyes do in ordinary vision. In modern photographic exhibitions one sees many pictures which have been taken with the lenses purposely out of focus in order to produce a more realistic effect.

One is not surprised to learn that it would be quite impossible to focus the pinhole picture upon a ground glass focussing screen; there is so very little light admitted to the camera that one cannot see the image. Fortunately there is no need of any focussing. No matter at what distance one places the photographic film from the pinhole, the image is always in focus. Of course, the farther away one places the sensitised film the larger will the image be.

There is another interesting point about pinhole photography, and this is a point in its favour. The definition of the picture is equally good for all objects, no matter at what distance they are away. This sentence may seem somewhat to contradict an earlier statement, in which I said that if one had a pinhole photograph of a large object taken from a short distance, one would see that there was a want of sharpness about the picture. There is really no contradiction. We do not notice the lack of definition in the distant landscape, but we should observe it in a large image of some detailed object.

This evenness of definition for all distances is practically perfect in lensless photography, while it is otherwise with lenses. Both the foreground and the background are often far out of focus.

Wherein, then, does the real disadvantage in lensless photography lie? The answer to this question must be obvious, for if one thinks of the total amount of light which can enter the camera through a pinhole, it must be clear that a very long exposure will be necessary to enable the faint image to affect the chemicals upon the photographic film. There is no use in attempting to increase the size of the hole; we should certainly admit more light, but the resulting image would be blurred. Indeed, if we made the hole large enough to admit a good light, we should find that no image at all would appear.

How long, then, does a pinhole exposure require to be? A fair idea of the exposure required may be gathered from the general statement that a pinhole photograph requires as many minutes as it would take seconds by an ordinary camera with a lens. Accordingly a picture which could be taken by an ordinary camera in one minute, would require an hour's exposure with a pinhole camera under the same conditions.

The chief purpose of a lens, therefore, is to admit more light into the camera, and still bring the image to a focus. The old-time Italian philosopher, Battista Porta, found that the pictures in his camera obscura were greatly improved when he placed a lens at the hole in his shutter.

It will be obvious that the more light a lens can pass into a camera the better will it be for instantaneous photography. Hence we hear of rapid or instantaneous lenses.

As we are not considering the subject from a practical standpoint, we need not trouble ourselves with the particular forms of lenses required for different purposes. It will be of more general interest to form some idea of the method of making photographic lenses.

It goes without saying that the lenses are made of glass, although there have been such things as liquid lenses. We all appreciate the light-transmitting qualities of glass, and none of us would care to return to the fourteenth-century open lattices or windows of oiled paper.

Most of us have some idea of the manner in which glass is made. Certain raw materials are mixed together and practically boiled in hot furnaces. Indeed, the whole process is not unlike the making of toffee, in which the ingredients, at certain stages, require to be stirred with a ladle.

If the raw materials used are compounds of sand, potash, and lead, then the resultant mixture is termed *flint* glass. If, on the other hand, the mixture is sand, soda, and lime, it is known as *crown* glass. Both flint and crown glass are used in the making of photographic lenses. A demand for finer work produced modifications of these. The new kinds of glass were first made in some works at Jena, in Germany, so that they are known as Jena glasses. These glasses are made by adding other ingredients, such as phosphorus, aluminium, etc., to the mixtures which are to be boiled.

One interesting point in the manufacture of glass is the method of obtaining a regular density throughout the mass. If the glass were more compressed in one part than another, the power of bending the rays of light would vary accordingly in different parts of the glass. The glass-maker meets with a troublesome difficulty here, for if he withdraws his glass from the furnace, the outside of the mass will cool more quickly than the inner portion. This cooling of the outside will cause a greater pressure upon the inside portion, so that it will become more dense. What can the glass-maker do to obviate this serious fault? He must cool the glass very gradually by means of ovens, in which he can bring the temperature very gradually down. The whole mass will then cool equally, and the process is called *annealing*. Large discs of glass may require many weeks during which they are gradually cooled.

Some of the glasses which are most suitable for photographic lenses are necessarily of a soft nature, owing to their composition. They are therefore much more easily scratched than is ordinary glass; hence the care required in cleaning fine photographic lenses. It is a curious fact that these glass lenses are somewhat elastic. Indeed, if the lens-maker is not very careful in mounting a fine lens in its metal socket or cell, he may spoil the focus of the lens by making the cell press too tightly upon the edge of the lens.

Another curious point about some kinds of glasses is that they tarnish on exposure to air just as easily as iron rusts. When the lens-maker uses this kind of glass, he must protect it from the air by enclosing it between lenses made from another glass which will not tarnish.

If lenses could be cast in moulds, in the same way as glass ornaments, the prices would be very different from what they are, but, unfortunately, this cannot be. A block of glass has to be cut and then ground down to the required shape. In grinding, the glass is rubbed against a hard metal tool, or mould, of the desired shape, while emery, sand, or diamond dust, is placed between the surface of the glass and the tool. The glass is caused to assume gradually the shape of the tool.

For simple lenses, such as are used in spectacles, and for cheap lenses, this process of grinding may be deputed to automatic machines. Photographic lenses, however, not only require skilled labour, but the making of fine lenses can only be accomplished by a certain delicacy of touch upon the part of the operator.

After the lens has been ground to the desired shape it requires to be polished to remove the marks of grinding. The polishing is very similar to the grinding process, except that rouge powder is used in place of the emery, and a mould or tool having a softer surface, such as cloth or wax, replaces the hard metal tool. By this means the lens is given a lustrous "black" polish. An imperfect polish will scatter the light into the camera, and this will be detrimental to the image.

The great delicacy of the work necessary in making fine lenses may be appreciated when we learn that before the operator can measure the results he has produced in the lens he must let the lens cool down to a perfectly even temperature. The curvature of the lens will alter with an unequal temperature.

Modern photographic lenses are made up of a combination of several different lenses, and are fitted together like a short telescope. As already indicated, the forms of these vary greatly according to the particular purpose for which they are intended. We find lenses described as portrait, view, rapid-landscape, wide-angle, tele-photo, universal, etc.

One point of interest is that the focus of a lens—its focal length—is not dependent alone upon the shape or curvature of the lens. The composition of the glass has a great deal to do with determining the focus. Two lenses of exactly the same form may bend the rays of light in different degrees. If the two lenses are made of different kinds of glass, the one may bring the rays to a focus at three inches from the lens, whereas the other's focal length may be six inches.

There is another interesting point in connection with photographic lenses, and this was observed at a very early date in the history of photography. In the *Philosophical Magazine* of October, 1839, there is a letter addressed to the editors by Dr. John T. Towson, and entitled "On the

Photo by *Rev. J. B. Thomson, Greenock*

PHOTOGRAPHS TAKEN THROUGH A PINHOLE

These beautiful photographs were taken without any lens; simply a dark chamber with a pinhole to admit the light. (See chap. xxi.)

Proper Focus for the Daguerreotype." In this letter the writer points out that lenses, as then known, did not bring the chemical rays of light to a focus at the same point as the visible or luminous rays. Therefore, when Daguerre focussed his picture on the ground-glass screen, he was not finding the true focus of the chief rays which affected his photographic plate. The picture would appear in good focus upon the screen, but the "invisible image" formed by the chemical rays would be out of focus, and the resulting picture would therefore be in the same condition. The yellow rays of light produce the greater part of the illumination, and it is well known that these yellow rays have practically nothing to do with the production of the picture, as is shown by the use of a yellow lamp in the dark room.

In his letter, Dr. Towson goes on to ask how Daguerre succeeds in producing such good results, and the writer explains it in this way. He points out that Daguerre "stops down" his lens, so that light only passes through a small portion at the centre of it. In this way only the rays which require least bending are allowed to enter the camera, or, in other words, only the light which is making a fairly straight course for the photographic plate gets in. Those rays which strike the lens at a considerable angle and would therefore require to be greatly bent are not accepted, for the greater the bending which takes place the more exaggerated will be the difference of focus between the visible and the chemical rays. The reader is not to imagine that none of the visible rays take part in the making of a photograph; but this subject will fall better within the title of the following chapter.

This closing up of the greater part of the lens by Daguerre, necessarily meant a long exposure, and therefore Dr. Towson proposed that a large lens might be used if it was corrected so as to bring all the rays of light to one and the same focus. The particular object in view was the possibility of taking portraits from life, so this new lens was termed a portrait lens, and it required a very short exposure as compared with Daguerre's previous achievements.

Having witnessed the bending of light in the illustrations opposite page 254, I do not think that any reader will have a difficulty in understanding how it is that a glass lens bends the rays. The bending occurs when the rays pass from a medium of one density (the air) into a medium of a different density (the glass), and again as the rays leave the glass and enter the air. The bending is therefore controlled by the curvature of the lens on both sides.

I have repeatedly heard amateur photographers say that it is altogether a matter of chance whether one gets a good, bad, or indifferent lens when one purchases a camera. There is a certain amount of truth in this if one refers only to cheap cameras, and does not include expensive lenses. The reason for this is not far to seek. A great many defects may occur in the making of a lens, or flaws may be found in the glass only when the lens is polished and practically ready for use. The lens-maker has already expended a good deal of money on this faulty lens, and he can only afford to destroy it provided he is to get a compensative price for a good one when he does make it perfect. In the case of cheap lenses he must just do the best he can; some are sure to be better than others. With expensive lenses, however, the case is different; he is willing to throw on one side all those wherein any fault occurs, no matter at what point in the process of manufacture the defect is detected.

Very great perfection has been arrived at in the making of lenses, but it must be clear that these results cannot have been attained in any haphazard fashion, nor could they have been very well arrived at by experiment. If lenses had been plastic bodies, which could be tried first of all in one shape and then squeezed out into another form, a purely experimental method might have been possible. Although I have stated at one point that a lens is elastic, it goes without saying that the elasticity is very slight and that the lens is in no degree plastic. We have seen that the making of a lens is no simple matter, even when the operator already has the necessary tools bearing the exact formation required for the particular lens which he desires to make.

The curvatures of the lenses required have all been determined by mathematical calculation, and then a tool has been made in agreement with the form worked out by the mathematician.

CHAPTER XXII

HOW LIGHT MAKES THE PHOTOGRAPH

The chemical action of light—The latent image—A simple demonstration—What is "chemical change"?—A curious compound—Light decomposes some substances—What happened on Daguerre's plates—A simple analogy—Modern photographic plates—Developing and fixing—Photographic papers—Toning and fixing the prints—The rays of light which take part in photography—What are orthochromatic plates?—Special purposes of other plates.

THE careful housewife, especially if she lives in the country, makes use of the direct chemical action of light, although she may not be aware of the fact. When she finds that the modern laundry has failed to make her cotton fabrics white enough, she simply passes the order on to the great bleacher Light. She places the cotton fabrics, in a wet condition, out of doors, and, as she says, "bleaches them in the open air." She really gets Light to do what the chemical agencies of the laundry-man have failed to do to her satisfaction.

This may not appear to be a very suitable analogy for the effect of light upon a photographic paper. The former is a bleaching-out process, while the latter is a colouring or darkening process. But if light can make some things white and other things black, then the difference must necessarily lie within the things which are being attacked by the light. It is obvious, therefore, that light is a force which sets up definite chemical actions, but that the particular effect produced will depend upon the nature of the substances themselves.

What about the latent or invisible image upon a photographic plate? In this case there is no visible change made by the light, but that there has been a real change effected may be demonstrated at the expense of a couple of photographic plates. Suppose that we have two similarly sensitised photographic plates, each enclosed in a dark envelope. We open one of the envelopes and take the plate out so that the daylight may fall upon it for a moment. We take care that the other plate is well protected from light. We then take the two envelopes into the dark room, and examine the plates by the light from a red or yellow lamp. Both plates look exactly alike; there is really no visible change. Each plate has a creamy white film over one side. We place the plates side by side in a developing tray filled with a certain chemical solution, and very soon we see that there is a marked difference between the two plates. One of the plates has become black all over, while the other remains unchanged. The change has taken place in the plate which was momentarily exposed to the action of light.

If we now place the two developed plates in a fixing solution, we shall find the white film to clear off the plate unaffected by light, so that it becomes practically a clear sheet of glass, although there remains a transparent gelatine film. The black plate comes out of the fixing solution with practically the same appearance as it had when taken from the developing bath.

Now it is quite apparent that the two plates have had exactly the same treatment throughout, with the one exception, that light was allowed to attack the one and not the other. We require no further evidence to convince us that light has a very real action.

What, then, do we mean by *chemical change?* The question hardly calls for an answer. Almost every one knows that in nature there are a certain number of simple or elementary substances, and that all the rest of nature is made up of combinations or *compounds* of two or more of these *elements.* But we must not think of a compound as a mere mixture. We may mix ground rice and sugar together; we have not made a compound. The rice and sugar are there just as before, and we might separate them again; indeed, if we were to sprinkle some of the mixture into a glass of water, we should see the sugar fall quickly to the bottom of the glass, while the ground rice would float upon the surface for some time.

If we think of any common chemical compound, we shall see at once how different it is from a mere mixture. We know that common table salt is a compound of sodium and chlorine. Now sodium is a soft metal, which one may cut with a knife, and which if cast upon a wet surface will catch fire. Fortunately for us, sodium behaves in a more orderly manner when it enters into partnership with chlorine. If it were otherwise we could not drop it into our soup and place it within our moist mouths, without its immediately igniting. The other partner in this combination, which is known as *sodium chloride* in the chemical "directory," or as common salt in the household, is the gas chlorine, which possesses a strong suffocating odour.

We might take water as another example showing how completely the elements lose their individuality while they are in partnership. We know that water is entirely composed of two gases—hydrogen and oxygen; but when we drink water we do not drink a mixture of gases. We see then that chemical change means more than a mere addition.

The chemical effect of light is not necessarily a combination or union of two or more substances. Light causes some combinations to disunite or decompose.

If we wish to impress any one with the fact that light causes certain substances to unite, we have a well-known experiment at hand. If some chlorine and hydrogen gases are mixed together in a glass globe and then exposed to light, the gases will unite in a vigorous manner, announcing their union by a considerable explosion. Fortunately the chemical changes which occur on our photographic plates are not of such a sensational character.

It will be of interest to form some idea of the way in which light makes the photograph. Our best plan will be to consider in the first place what happened on Daguerre's silvered plates. It will be remembered that the first step in Daguerre's process was to get iodine to unite with the silver coating on the surface of his copper plate. This he accomplished in a very simple manner. He heated the iodine so that some ascended in the form of vapour, and in this form it came in contact with the silver of the plate. The two substances united chemically. For our present purpose we must be content to think of these two substances as having a natural attraction or affinity for each other, thus causing them to join in partnership.

It will be obvious that the partnership is not a very permanent one, for Daguerre had to take great care to keep his prepared plate away from the gentle action of light until such time as he had it arranged in position in his dark camera. The combination must be a very unstable one when it can be so very easily upset or altered by the action of light falling upon it. This very instability gave Daguerre his chance of success.

Having got his plate safely within the dark camera, Daguerre opens the lens, whereupon a light-and-dark image falls upon the prepared or sensitised plate. We picture a chemical commotion wherever light attacks the plate, while the original partnership still holds good at such places as lie under the dark parts of the image. An examination of the plate in the dark room would not show any visible change, and so we remember that it was by means of an accident that Daguerre discovered that there had been a real chemical change upon his plate. I refer to the magic cupboard, in which the good fairy "mercury" produced a beautiful picture upon a plate which had shown no sign of change whatever when taken from the camera. And thus it was that Daguerre discovered that by exposing the invisible image to the vapour of mercury a visible picture was formed. But what made the picture appear?

Suppose, by way of analogy, that we had an iron target in which was embedded the design of a crown made of soft clay. Matters are so arranged that the clay and the iron look exactly alike, and the whole forms a smooth, self-coloured surface. If we commenced throwing handfuls of white stones at the target, we should very soon find that some of the stones were sticking to some parts of the target and not to others. We therefore take good care to strike every part of the target, and when we have done so we shall find the design of a crown standing out distinctly upon the unaffected background of the target.

The foregoing is certainly a very crude analogy, but it may be of assistance in making clear what happens when the plate with the invisible image is exposed to the vapour of mercury. The plate has been prepared by the artist Light; there is an invisible design. We bombard the plate with small particles of mercury, and these unite with that part of the surface which has been specially prepared by light. Those particles of mercury which strike the parts of the plate with which light has not meddled are simply thrown off again. These are represented in the analogy by the stones striking the iron parts of the target. In this way Daguerre's beautiful pictures were built up.

It will be observed that the parts of Daguerre's plate which were not affected by light still remained sensitive to light, the plate having been kept all this time in the dark. It was therefore necessary to wash the remaining portion of this sensitive film away. This Daguerre did by washing the plate in salt water.

Turning to modern photographic plates, we find light preparing an invisible picture upon the unstable chemical surface. Then follows the developing bath, and we imagine the chemicals in the developer to be attracted by the prepared design and rejected by the unaltered portions of the chemical film. Thus the visible image appears in the film, but we must remove the unaffected portions. This process is known as "fixing," but would be more descriptively named if it were called a "clearing" process. The chemicals in this bath have no effect upon the developed image, they simply dissolve away the unaffected portions of the film, which if allowed to remain would darken on further exposure to light, and thus destroy the picture.

Leaving the production of the image upon the glass negative, we turn to the photographic print on paper. We have become familiar with the fact that light produces a visible image upon one kind of photographic paper, while it produces a latent image upon another kind of paper. The former is called a "printing-out-paper" (P.O.P.), and the active part of the sensitive coating is composed of silver chloride. The action of light is to darken the silver chloride, and so the chemical change is visible at once. Exactly what the chemical change is has not been definitely determined, but the darkened substance possesses less chlorine than it did before it was attacked by light.

The colour produced by this darkening process is not very pleasing, but it may be altered by washing the print in a "toning" bath containing a solution of chloride of gold or other metal. The print is still sensitive to light, and what really happens is that the toning solution deposits a very finely reduced powder of gold upon the darkened portions of the print. This operation is carried out in daylight, because the sensitive coating is not so easily affected by light as that upon a sensitised photographic plate.

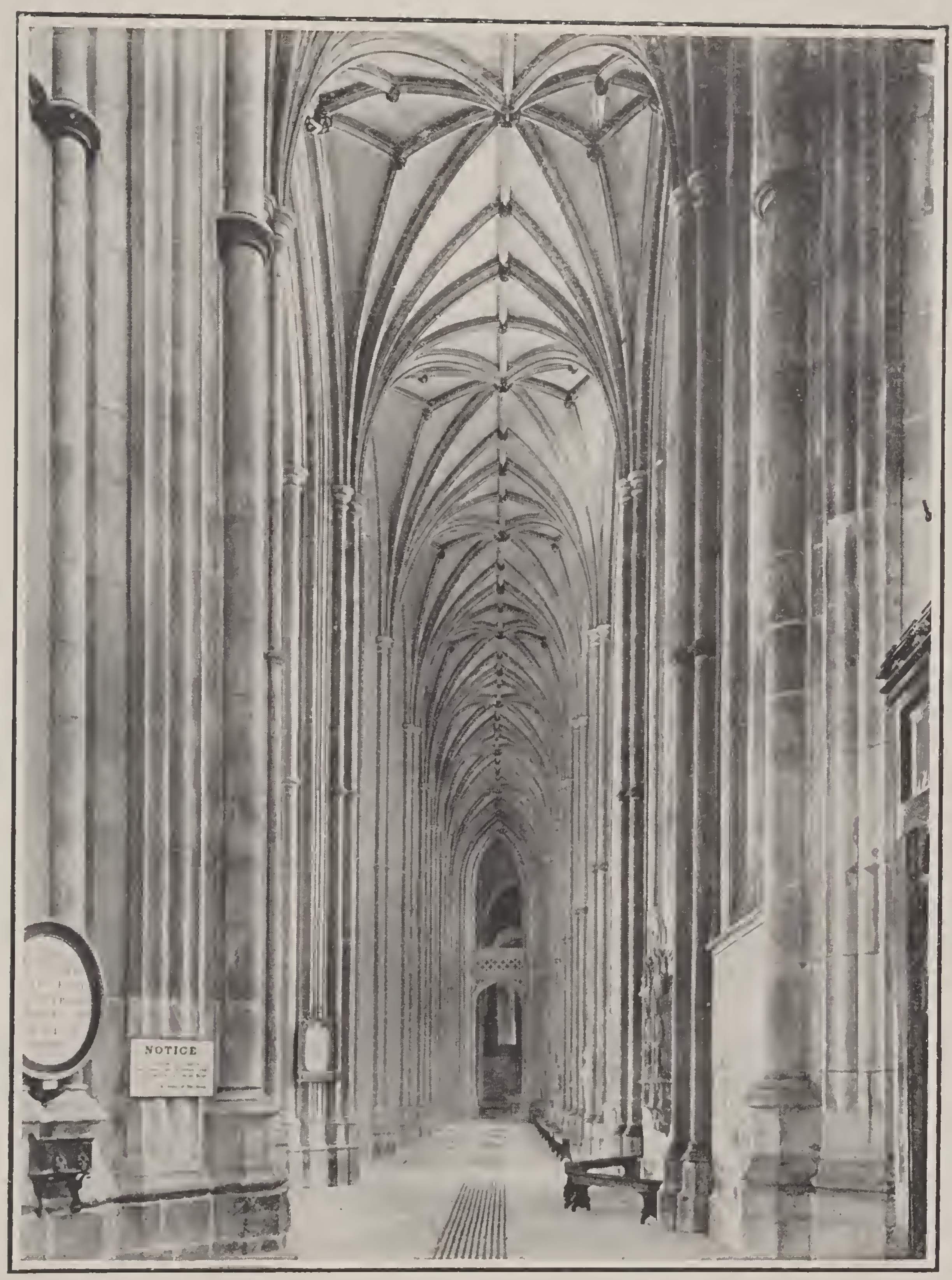
After the print has had a more pleasing colour produced by the toning bath, it is necessary to remove all the unaffected portions of the still sensitive coat. This is done by another chemical bath, originally salt water, but now a solution of hyposulphite of soda is used. This process, although simply a clearing process, is known as "fixing the print."

Having already considered the development of the latent image on the photographic plate, we need not trouble further with the similar development of the invisible image produced on bromide paper. In this case the developed image will be a positive, as it has been printed through a negative.

As the present volume does not endeavour to give any suggestions for the practice of photography, it may seem unnecessary to remark that the negatives and the prints are always well washed between each chemical bath. It is necessary to stop one chemical action before setting up another, and one does not wish to carry chemicals from one bath into another bath.

In some of the earlier chapters I have had occasion to refer to the fact that ordinary daylight contains red, orange, yellow, green, blue, indigo, violet, and a great quantity of invisible rays. This fact is well demonstrated by analysing a beam of light through a glass prism. We have no difficulty then in testing the different part that each kind of light plays in photography. We have already seen that this spectrum, falling upon a sensitised surface, makes practically no change where the red and orange rays fall. The yellow rays are almost equally inactive, while the green rays have also very little action. Looking at the visible spectrum, we have only blue, indigo, and violet rays left, and it is these rays, more particularly the bluish violet, which attack the chemicals upon the ordinary photographic plate. It will be remembered, however, that an attack is also made by an invisible foe, for the sensitive surface is affected far beyond the violet end of the spectrum. Indeed, we have seen that it is possible to take a portrait by means of these invisible rays alone (see illustration facing p. 196). We are therefore quite familiar with the fact that a large proportion of the light which makes our photographs is quite invisible, and, indeed, that the very rays (yellow) which give us most light, according to our estimate of luminosity, are practically of no use in photography with ordinary plates.

Attempts have been made to produce a photographic plate which should be affected by all colours in similar proportions to the effects produced in vision. It is impossible to do this perfectly, but the great difference between the ordinary photographic effect and that of our vision may be very considerably reduced, so that any coloured object may now be photographed without such strange results as might otherwise be produced. By way of illustration, let us take some extreme case. It may be asking too much of the reader to imagine a lady dressed in a bright yellow dress with blue trimmings upon it, but suppose we have found the required subject in a



By permission of *the Thornton-Pickard Co., Ltd.*

AN INTERIOR (CANTERBURY CATHEDRAL)

This photograph required an exposure of one hour, and was taken with a Thornton-Pickard Ruby camera. The very high roof made it a difficult subject, but it was overcome by having a rising front on the camera.

circus rider. Her photograph would represent her in a black dress with light trimmings. The photographic chemist, however, has prepared surfaces which are sensitive, in certain degrees, to red, orange, yellow, and green rays. Plates prepared in this way are called *orthochromatic.*

The purpose of these orthochromatic plates is to reproduce in the photograph a true proportion of light and shade. A yellow object is to look lighter and not darker than a blue object, as is the case in ordinary photographic plates, and so on.

Then again we have plates specially prepared to be sensitive to one colour in particular, and these are of great service in photographing through the colour screens for the three-colour process of printing.

When considering invisible rays, in an earlier chapter, we found that photographic plates had even been made sensitive to the rays below the red end of the spectrum. These, however, are of scientific value alone.

The chemistry of photography is a very complex subject; much mystery still remains, and a thorough understanding of the knowledge that has been attained requires one to be familiar with chemical symbols and equations. It has only been possible in this chapter to give a very general idea of the way in which light makes a photograph.

CHAPTER XXIII

CONCLUSION

AMONG all the wonderful things that were discovered during the fruitful nineteenth century, *photography* must ever hold a very high position. We have all become so familiar with the art that we have almost ceased to marvel at its achievements.

We have no photographs of the late Queen Victoria as a girl. Even when she ascended the British throne there were no photographers to record the coronation scene. At that very time Daguerre, in France, and Fox Talbot, in England, were busy trying to entrap the image of the camera obscura. Now there are tens of thousands of men making photography their daily business, while a census of all the amateur photographers throughout the civilised world would make a library of very bulky volumes.

If one seriously considers the fact that a whole living scene may be registered by photography in one-thousandth part of a second, one cannot but be impressed with the marvellous achievement.

Think what a small fraction of time a second is, and try to imagine one-hundredth part of that. Then look at the illustration facing page 268, and consider that the whole detail of that picture was recorded in one five-hundredth part of a second. It is, indeed, difficult to realise this fact.

CONCLUSION

Of all the wonders related in connection with photography, I think the phenomenon of the latent image remains the most extraordinary. We place a plate with a chemically prepared surface in a dark box, which has a small opening with a glass window formed by several pieces of curved glass. We have a dark blind over this window, but we withdraw the blind for the smallest fraction of a second. What has happened? We take the plate and examine it in a dark room by the aid of a red lamp. We see the plate exactly as it was when we placed it in the camera. We wash the plate in a chemical solution and a real picture almost immediately appears.

Suppose for a moment that some one individual had discovered all this on his own account, before Daguerre or Fox Talbot had ever dreamt their first philosophic dreams of recording the image of the camera obscura. Imagine this one ingenious individual calling together a dozen learned men of his time. He explains to them that he can get light to give him a perfect picture at a moment's notice, and he proposes to demonstrate this fact.

We picture the twelve philosophers watching the inventor place his prepared plate within the dark box. They examine the prepared plate in the dark room, and are all satisfied that it contains no hidden picture. The very darkness of this room, however, appeals to most of them as a rather suspicious feature. The red illumination is very subdued. Going out of doors, they watch the experimenter arranging his dark box on its stand. Light is to draw the view before them. The onlookers marvel at the audacity of the man, merely lifting off the dark shutter for a single moment. Another examination in the dark room, and all declare that the experiment is a failure, there is not the least sign of any picture. When the inventor explains that the picture is really there although it is invisible, I can imagine the twelve good men joining in a hearty laugh. The chemical bath into which the inventor proposes to put the pictureless plate is next examined, but there seems no room for any trickery there. With what incredulity would the onlookers watch the plate as the inventor made the chemical solution flow to and fro over it. At last the semblance of a picture does appear. Another chemical bath for the plate, and the inventor hands it to one of the amazed philosophers to take out into the daylight. Truly marvellous, but, alas, everything is reversed! Black objects appear white, white objects appear black, and the right and left hand sides of the picture are transposed. The inventor explains that this reversal, instead of being a disadvantage, is exactly what he desires, for he proposes giving each philosopher a corrected copy of the picture.

The inventor produces a large sheet of white paper which he has prepared. He asks any one of the onlookers to cut from this sheet twelve pieces of paper, each equal in size to the glass plate. There can be no trickery here, for if the paper did contain any hidden pictures they would run a certain risk of being cut through the centre. This time the inventor explains that he will save the gentlemen the trouble of leaving the dark room. Having placed the glass picture on the top of one of the pieces of prepared paper, he simply produces a bright flash of light. He then places this piece of apparently pictureless paper in a chemical bath, and very soon a picture appears. Another chemical bath and the picture is handed to the philosophers, who hasten to examine it by daylight. This picture is true to nature—black objects appear black, white appears white, the right and left hand sides are as they should be, and the whole variety of light and shade is perfectly portrayed.

Of course, this demonstration never occurred just in the manner here described. I have merely asked the reader to draw upon his imagination in order to impress him with the true romance of photography. It has all happened, but not just so suddenly. Who can fail to be impressed with Daguerre's accidental discovery of the latent image? It reads far more like a fairy tale than real life.

There must be few homes to-day in any civilised country in which photographs are not to be found. In many of our homes there are hundreds of such pictures.

Passing over the sentimental side of the subject, it must be obvious to all that our knowledge has been very greatly extended by such photographs as travellers in distant lands have obtained and brought home. Every traveller is not an artist; but, armed with a camera and photographic plates, he can bring home faithful pictures of all the curious tribes and people he meets. We see the natives' huts, their mode of living, and the strange vegetation. In connection with exploration alone, photography has been of the very greatest interest and service.

Instead of "killing" the painter's art, photography has been of great assistance to the artist, in recording details which it would take too long to draw from nature. Then we benefit by the photographic reproductions of artistic masterpieces.

We have seen how it is photography that provides us with the beautiful book illustrations of the present day.

We have also seen how the eye of the camera has been able to look farther into the heavens than the human eye can do. Photography has faithfully recorded the presence of stars which man can never hope to see, even with the very best of telescopes.

By means of photographs taken through the microscope, the student may examine the invisible germs of disease and learn to recognise the forms of different bacteria.

The surgeon photographs the living skeleton and records the daily progress of a troublesome fracture. Indeed, photography enters into the whole realm of science, assisting in a multitude of different ways.

Returning for a moment to the pictorial side of the subject, and passing over the marvellous living pictures which photography gives us through the medium of the cinematograph, it is interesting to note that permanent records of important subjects are being stored in the British Museum and elsewhere. *The National Photographic Record Association* reports that about four thousand records have been lodged already in the British Museum alone. These should prove of great interest to future generations.

As regards the future of photography, he would be a bold man who would prophesy. Colour photography has got on to new lines recently, and its future looks more hopeful.

CONCLUSION

It has now been found possible to transmit photographs by means of electricity. Is it possible that some day we may yet be able to see the distant friend as he speaks to us by telephone?

It must be admitted by the least enthusiastic that during the last fifty years photography has done extraordinary things; and may we not hope that still more wonderful achievements will be accomplished by this great invention of the nineteenth century?

APPENDIX

THE more studious reader may be glad to have the following synopsis of historical facts and dates, arranged in a convenient form for reference.

DISCOVERY OF PHOTOGRAPHY

1550

The alchemists of the sixteenth century observed that silver ores changed colour when taken from the mine. They also made silver nitrate.

1558

Giovanni Battista della Porta exhibited a camera obscura to his friends in Italy; he was not the inventor.

1727

Johann Heinrich Schultze, a German physician, amused his friends by getting light to print stencil designs upon a liquid mixture of chalk and silver nitrate. He then caused the printing to disappear by shaking the bottle. It is obvious that he only looked upon the phenomenon as an amusing incident.

1737

Hellot coated paper with a solution of silver nitrate, and showed that it was darkened by exposure to light. His only concern, however, was to make a secret ink. The solution was colourless, and hence the writing was invisible until exposed to light.

1774

Charles William Scheele, a Swedish chemist, studied the chemistry of the action of light on silver salts. He found that the violet rays of the spectrum were by far the most active.

APPENDIX

1791

Thomas Wedgwood, a son of the great potter, made contact prints of opaque objects upon paper prepared with silver salts, but he could not fix them.

1795

Lord Brougham is stated to have suggested a way of making "permanent" the image of the camera obscura, by allowing it to fall upon a "surface of ivory rubbed with silver nitrate." He sought to do this through the Royal Society, but he declared afterwards that the secretary deleted this suggestion from the paper. No doubt it was considered impracticable.

1801

J. W. Ritter, of Jena (Germany), discovered that paper prepared with silver chloride was darkened by the invisible rays beyond the violet end of the spectrum.

1802

Thomas Wedgwood and Sir Humphry Davy read a paper before the Royal Institution (London) on securing copies of drawings made on glass, by placing these in contact with paper or white leather prepared with silver nitrate. They failed to make the prints permanent. These experimenters tried to entrap the image of the camera obscura, but found the light insufficient for the chemicals upon their paper.

1810

J. T. Seebeck was able to produce the colours of the spectrum upon moist chloride of silver. The results were very imperfect and could only be examined in a very subdued light, while they soon disappeared on exposure to the air.

1813

Joseph Nicéphore Niépce, of Châlons-sur-Saône, France, tried to prepare lithographic stones by the action of light. He made the drawing transparent and then tried to print it on to the surface of the stone, which he had previously treated with silver salts. He could not fix the results; the stone soon blackened all over its surface.

APPENDIX

1816

Niépce tried seriously to fix the image of the camera obscura. With very long exposures he obtained some imperfect results, but could not fix them. A few years later he was successful in making permanent prints of drawings on bitumen of Judea. He called his process "heliography." His next attempt was to fix the image of the camera obscura by this means, and he succeeded in some measure, though the pictures must have been more like shadows or profiles.

1824

Louis Jacques Mandé Daguerre, a scene painter in Paris, endeavoured to fix the image of the camera obscura, in order to help him in his profession. He first of all tried the silver salts, but with little success.

1829

Niépce and Daguerre revealed their secrets to one another and joined in partnership.

1833

Niépce died, having seen but little advance during his partnership. Daguerre soon abandoned the old process and got on to new lines.

1835

William Henry Fox Talbot, an English gentleman of means, who had been making experiments since 1833, succeeded in obtaining pictures of his country residence, by means of the camera obscura and paper prepared with silver salts. He had not heard of the experiments previously made by Wedgwood and Davy, nor was he aware that Daguerre was at work upon this subject in France.

1838

Daguerre accidentally discovered a means of developing the latent image. Along with Niépce junior, he received a pension from the French Government for disclosing the secret of the daguerreotype process.

APPENDIX

1839

Fox Talbot, disappointed at having been forestalled by Daguerre, made known his process of "photogenic drawing." Talbot's invention was really the basis of modern photography. He produced a negative from which any number of positives could be printed.

1839

Some months later Daguerre's process was publicly explained in Paris.

1839

Sir John Herschel proposed hyposulphite of soda for "fixing" the pictures instead of common salt, as formerly used.

1840

J. Goddard, a lecturer in London, applied bromine to Daguerre's plates, along with the iodine, and made a much more sensitive surface, thus greatly reducing the time required for exposure.

1840

Photographic studios were opened in Great Britain.

1841

Special photographic lenses were made for the first time. These reduced the time of exposure to one-tenth of that previously required.

1841

Fox Talbot patented his later process of "calotype," in which the sensitiveness of his paper negatives was greatly increased. He used iodide of silver and a solution of gallic acid and silver nitrate.

1841

Up to this time the processes of developing, etc., were carried on in total darkness. At this date a patent was taken out for the use of red lamps.

1848

Niépce de St. Victor, a nephew of the original Niépce, introduced the process of coating glass plates with albumen containing iodide of potassium, and then sensitising them by dipping them in a bath of silver nitrate before exposing them.

APPENDIX

1851

Frederick Scott Archer, a London sculptor, introduced the wet collodion process.

1855

Dr. Taupenot, in France, produced the first dry plates.

1864

Sayce and Bolton used collodion emulsion for making dry plates.

1871

R. L. Maddox substituted gelatine for the collodion emulsion, but these plates did not come into use till some years later.

BOOK ILLUSTRATIONS

1826

Niépce copied drawings in line on to metal plates by means of light. He prepared the plates with a surface of bitumen of Judea, and etched the exposed lines with acid. He used the etched plates for printing.

1839

Mungo Ponton demonstrated the fact that potassium bichromate, when dried, was changed by exposure to light, and that the unexposed parts might be washed away. This gave us the basis of the modern processes of transferring photographs to the surface of printing blocks. A few years later Fox Talbot practised what we now call photogravure.

1876

Zincotype, or line drawings reproduced on zinc blocks, by photography.

1884

Half-tone process, by which any photograph may be reproduced on printing blocks.

1896

The three-colour process of printing.

APPENDIX

MISCELLANEOUS

1892

Animated pictures. Edison's kinetoscope, followed in 1895 by Lumière's cinematograph.

1895

Colour photography. Ives, of Philadelphia, took three separate photographic records, through red, green, and violet colour screens. He then reproduced the colour picture by means of three magic lanterns, using the same colour screens. All the other processes of colour photography were subsequent to this.

1895

X-ray photography.

1907

Professor Korn perfected his system of telegraphing photographs over great distances.

It may be of interest to note how the time of exposure required for taking photographs was gradually decreased by each successive invention.

Niépce's heliography in 1827 required an exposure of 6 hours.
Daguerre's process in 1839 (afterwards greatly reduced) „ „ 30 minutes
Talbot's calotype in 1841 „ „ 3 minutes
Archer's wet collodion in 1851 „ „ 10 seconds
Dry plates (gelatine) in 1878 „ „ 1 second
Fast plates to-day „ „ $\frac{1}{1000}$th second
Electric spark photographs taken in about $\frac{1}{1000000}$th second

It may also be of interest to note the different periods during which the different processes held sway.

Daguerreotype was practised from 1839 to 1854.
Talbotype „ „ 1841 to 1855.
Wet collodion „ „ 1851 to 1880.

After this the arrival of the dry plate very quickly made photography a popular pastime.

THE END

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